

## Course Glossary

Glossary entry headings that are followed by an asterisk (\*) are terms that we expect you to be able to explain the meaning of, and use correctly, both during your study of the course and at the end of the course. We do not necessarily expect you to remember definitions of the other terms; they are included here for convenience. Cross-references within entries to other Glossary entries are indicated by underlining. Each entry indicates the block in which the term is introduced (e.g. B3 is Block 3), or developed further in the case of cumulative entries. If a term is introduced *only* in an activity, this activity number is also given (e.g. B3, A12.1 is Block 3, Activity 12.1).

**30-year mean surface temperature\*** The Earth's surface temperature at some location or over some region, averaged over a period of 30 consecutive years. Averaging over 30 years is a convention used by meteorologists to characterize measurements of climatic conditions, such as surface temperature and rainfall, which reduces the influence of short periods of unusual or un-representative conditions. (B2)

**abbreviated structural formula\*** A simplified structural formula that shows explicitly only the chemical bonds between carbon atoms that form the backbone of a molecule together with any bonds to functional groups. Examples are  $\text{CH}_3\text{—CH}_2\text{—CH}_3$  (propane) and  $\text{CH}_3\text{—CH}_2\text{—OH}$  (ethanol). (B8)

**absolute age\*** The quantitative age of a geological material or event. Most absolute ages are obtained by radiometric dating techniques. Compare with relative age. (B10)

**absolute plate motion\*** The speed and direction of movement (i.e. the velocity) of a lithospheric plate with respect to a fixed frame of reference, typically to a hot spot within the Earth's mantle. (B3)

**absolute temperature scale\*** (Also known as the Kelvin scale.) A temperature scale for which the zero corresponds to the lowest possible temperature, absolute zero. The unit of temperature on this scale is the kelvin, and this is the SI unit of temperature. To convert a temperature on the absolute scale into a temperature on the Celsius scale, you subtract 273.15 from the numerical value of the temperature in kelvin. (B5)

**absolute zero\*** The lowest possible temperature. At this temperature the atoms and molecules in a substance have the minimum possible kinetic energy. Absolute zero is 0 kelvin (K) on the absolute temperature scale, and  $-273.15^\circ\text{C}$  on the Celsius scale. (B5)

**absorption\*** (of radiation) An interaction between radiation and matter, in which the energy of the radiation is converted into other forms of energy. (B2)

**absorption line\*** A spectral line produced when atoms of a particular type absorb photons with a particular energy. An absorption line appears dark on a bright background. (B7)

**absorption spectrum\*** A spectrum produced when light (or other electromagnetic radiation) with a continuous range of wavelength (or frequency or energy) illuminates a substance and light of certain wavelengths (or frequencies or energies) is absorbed. If the illuminated substance is gaseous atoms, e.g. sodium vapour, the absorption spectrum contains dark absorption lines, corresponding to transitions between atomic energy levels, superimposed on a bright continuous spectrum. (B7)

**absorptivity** The fraction of the power in the radiation incident on an object or substance that is absorbed by the object or substance. (B2)

**abyssal plain\*** The part of the ocean floor that lies between 4 and 6 km below the surface. Abyssal plains are generally flat and they make up the major part of the ocean floor. (B3)

**acceleration\*** The rate of change of velocity. In SI units acceleration is measured in metres per second per second ( $\text{m s}^{-2}$ ). (B3)

**acceleration due to gravity\*** The acceleration of an object that is falling freely under the influence of a gravitational force. Usually applied to the acceleration of objects close to the Earth's surface, where the acceleration of any freely-falling object has the value  $g = 9.8 \text{ m s}^{-2}$  irrespective of the mass of the object. (B5)

**accurate\*** A set of measurements is accurate if there is only a small systematic uncertainty associated with them. (B2)

**acetyl\*** The two-carbon group removed from pyruvate in the link reaction and transferred to the TCA cycle in the form of acetyl CoA. (B9)



**acetyl CoA\*** Acetyl (2C group) combined with coenzyme A, and formed by the link reaction. (B9)

**acid\*** A substance that contains hydrogen atoms and yields aqueous hydrogen ions when it dissolves in water. The solution usually has other characteristic properties, such as the capacity to turn blue litmus red, to liberate carbon dioxide from calcium carbonate and to react with metals to produce hydrogen gas. (B6) An acidic solution is one in which the hydrogen ion concentration is greater than  $1.0 \times 10^{-7}$  mol litre<sup>-1</sup> at 25 °C. *See also* pH scale. (B8)

**active site\*** The region of an enzyme that binds the reactant, or substrate, molecule and catalyses its transformation into product(s). The active site has specific groups arranged in just the right positions to provide the substrate with an ideal environment for reaction. Only particular compounds will have the correct groups in the correct geometry to bind to the active site, and this is the origin of the substrate specificity of enzymes. (B8) Enzyme catalysis involves the formation of an enzyme-substrate complex which then breaks down into product(s). Compare with binding site. (B9)

**adaptation\*** A character that suits an organism to its way of life by increasing the probability that it will survive and reproduce in the environment in which it lives; also the process by which such a character arises. (B4)

**addition polymer\*** A polymer formed from monomers that contain a carbon-carbon double bond. The polymer is formed by monomers bonding together in an addition reaction without the loss of any atoms. (B8)

**addition reaction\*** A chemical reaction in which two atoms or groups of atoms are added across a double bond. (B8)

**adenosine diphosphate\*** *See* ADP.

**adenosine triphosphate\*** *See* ATP.

**adipose tissue** Fat storage tissue made up of cells that each contain a globule of fat. (B9)

**ADP\*** A molecule consisting of an organic part — base plus sugar — and a short chain of two phosphate groups.  $\text{ADP} + \text{P}_i$  forms ATP when there is coupling of this reaction to an energy-releasing reaction. Conversely, ATP is converted into ADP and  $\text{P}_i$  when coupled to an energy-requiring reaction. (B9)

**aerobic respiration** The cellular reactions in which oxygen is used to bring about the complete catabolism of organic compounds, such as glucose, to carbon dioxide and water. Much larger quantities of ATP are produced in this process than in anaerobic respiration. (B9)

**aerosol\*** A collection of tiny liquid or solid particles dispersed in a gas. (B2)

**aftershock** A smaller earthquake (usually one of a series) following a large earthquake. (B3)

**air resistance** When an object moves through the air, the air exerts a force that tends to slow down the object. This force does work on the object, and the object and air get warmer as kinetic energy is converted into internal energy. (B5)

**albedo** *See* planetary albedo.

**alcohol** A compound with molecules in which an —OH group is attached to a hydrocarbon group. Alcohols have the general formula  $\text{R-OH}$ . (B8)

**algae\*** Simple, often microscopic, plants which live in water or moist places and lack true stems or leaves. (B2)

**algebra** A branch of mathematics in which symbols are used to represent quantities, (algebraic) equations are written to represent the relationships between these quantities, and the equations are rearranged to solve problems. (B5)

**alkali** A substance that dissolves in water to give a solution of aqueous hydroxide ions that is capable of turning red litmus blue. The name is derived from the Arabic, *al-qaliy* (roasted ash), because such solutions can be made by adding water to the ashes of wood or plants. *See also* base (chemistry). (B6)

**alkali metals\*** The metallic elements lithium, sodium, potassium, rubidium, caesium and francium, so named because they dissolve in water to give solutions that contain significant concentrations of hydroxide ions. The alkali metals occur in Group I of the Periodic Table. (B6)

**alkaline\*** An aqueous solution that contains a concentration of hydroxide ions that is sufficient to turn red litmus blue. (B6)

**alkane\*** A hydrocarbon in which each of the carbon atoms is attached to four other atoms; such a compound is said to be a saturated compound because it contains only single bonds. (B8)

**alkene\*** A hydrocarbon containing a double bond between two carbon atoms, each of which is attached to two other atoms. Such a compound is said to be an unsaturated compound. (B8)

**allele\*** One form of a gene that can exist at a single gene locus. Often there are just two alleles, one frequently dominant to the other. Sometimes there are several alleles, only two of which are present in an individual, e.g. those responsible for the ABO blood group system of humans. (B9)

**allele frequency\*** The number of copies of a particular allele in a population, expressed as a proportion. Thus, if a particular allele is three times as common as its alternative(s), the frequency of that allele is 75% or 0.75. (B9)

**allopatric speciation\*** The divergence of two or more populations into separate species after they have become separated geographically. (B9)

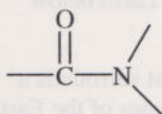
**alpha-decay\*** ( $\alpha$ -decay) The process in which an atomic nucleus decays to form a less massive nucleus with the ejection of an alpha-particle, e.g.

${}^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + {}^4_2\text{He}$ . Alpha-decay is one of the types of radioactive decay. (B6)



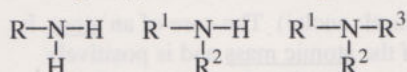
**alpha-particle\*** ( $\alpha$ -particle) The particle that is ejected in alpha-decay. An  $\alpha$ -particle is a helium nucleus, which is represented as  ${}^4_2\text{He}$  (or  $\text{He}^{2+}$ , because it is a helium atom stripped of both of its electrons). (B6)

**amide** A compound with molecules containing an amide group:



(B8) The amide groups formed between amino acids in protein molecules are usually referred to as peptide bonds. (B9)

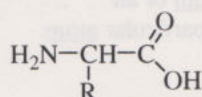
**amine** A compound with molecules containing an amine group, with one of the general formulae:



(B8) Amine groups are generally called amino groups in biology. (B9)

**amino acid\*** A compound that contains both an amine (amino) group,  $-\text{NH}_2$ , and a carboxylic acid group,

$-\text{COOH}$ . There are about 20 naturally occurring amino acids, which are particularly important in living things; these have the general formula



where R represents one of about 20 different groups. Amino acids are the monomers from which proteins are built. (B8)

**ammonite\*** A member of an extinct group of marine molluscs with a chambered, spiral shell. Ammonites were confined to the Mesozoic. (B10, A3.1)

**ampere\*** In SI units, the unit of electric current, represented by the symbol A, and often abbreviated to amp. The ampere is related to the coulomb by the relation  $1 \text{ A} = 1 \text{ C s}^{-1}$ . (B5)

**amplitude\*** (of a wave) Half the peak-to-trough displacement of a wave. (B7)

**amylopectin** The main component of starch, the energy storage polysaccharide found in green plants. Chemically it is very similar to glycogen, i.e. a branched chain of glucose molecules. (B9)

**anabolism** An alternative term for biosynthesis. (B9)

**anaerobic respiration\*** The cellular reactions that bring about the partial catabolism of organic compounds, such as glucose, in the absence of oxygen. Under these conditions, glycolysis occurs, but the link reaction, TCA cycle and the coupled reactions of electron transport and oxidative phosphorylation cannot occur. Yeast, respiring anaerobically, converts pyruvate to carbon dioxide and ethanol, and NAD is regenerated. Muscle tissue, respiring anaerobically, converts pyruvate into lactate, and NAD is regenerated. Much less ATP is produced than in aerobic respiration. (B9)

**analogy** An object or system that has similar features to an otherwise different object or system of interest, such

that it can be used to help explain or understand particular features of the object or system of interest. (B1)

**anaphase\*** The phase of mitosis in which the chromatid pairs formed during replication separate, so that each chromatid becomes a chromosome in its own right. One member of each pair is drawn to one end of the cell, and its partner is drawn to the other end. (B4)

**andesite\*** A fine-grained igneous rock intermediate in composition between basalt and rhyolite. The extrusive equivalent of diorite. It usually contains plagioclase feldspar and pyroxene, sometimes with amphibole, biotite mica, alkali feldspar and quartz. (B10)

**angle\*** A measure of the inclination between two straight lines. The unit of measurement for angles is the degree;  $90^\circ$  is a right angle, and  $180^\circ$  is the angle between opposite directions. (B2)

**angle of diffraction\*** The angle between the 'straight through' direction and a particular feature in a diffraction pattern. The angle of diffraction  $\theta_n$  of the  $n$ th diffraction order in the diffraction pattern produced by a diffraction grating is given by  $\sin \theta_n = \frac{n\lambda}{d}$  where  $\lambda$  is the wavelength of the light and  $d$  is the line spacing of the diffraction grating. (B7)

**Animalia\*** The formal name for the animal kingdom, one of four kingdoms within the domain Eukarya. (B4)

**annihilation\*** The process whereby a matter particle combines with its antimatter counterpart to produce photons of electromagnetic radiation. The mass of the matter and antimatter particles is converted into energy. For example, when a slowly moving electron annihilates with a slowly moving positron, the total mass of the two particles ( $511 \text{ keV}/c^2$  each) is converted into a pair of gamma-ray photons each of which have an energy of 511 keV. The opposite process is referred to as pair creation. (B11)

**annual** A plant that grows from seed, bears flowers, produces seeds of the next generation, and then dies all within a single year. An annual therefore undergoes reproduction once in the course of its life history. Compare with biennial and perennial. (B4)

**annual mean surface temperature\*** The surface temperature at some location or over some region, averaged over a single year. (B2)

**antibaryon\*** A subatomic particle composed of three antiquarks. The antimatter counterpart of a baryon. A type of hadron. Examples include the antiproton and the antineutron. (B7)

**antibody** A protein produced by particular types of white blood cell in response to attack from a pathogen. Each antibody has a binding site complementary with the pathogen molecule it recognizes. (B9)

**anticodon\*** A triplet of bases on a tRNA molecule that undergoes base-pairing to a triplet of bases, a codon, in mRNA during translation. (B9)

**antilepton\*** A fundamental particle, the antimatter counterpart of a lepton. There are six antileptons: the antielectron (or positron  $e^+$ ), the antimuon ( $\mu^+$ ), the



antitauon ( $\tau^+$ ), the electron antineutrino ( $\bar{\nu}_e$ ), the muon antineutrino ( $\bar{\nu}_\mu$ ), and the tauon antineutrino ( $\bar{\nu}_\tau$ ). (B7)

**antimatter\*** Every matter particle has a corresponding antimatter particle. The two particles have the same mass, but other properties, such as electric charge, are opposite. An antimatter particle and its corresponding matter particle can annihilate each other to release energy. Conversely, an antimatter-matter pair of particles can be created from energy. (B7)

**antiquark\*** A fundamental particle, the antimatter counterpart of a quark. There are six types (flavours) of antiquarks: antiup ( $\bar{u}$ ), antidown ( $\bar{d}$ ), anticharm ( $\bar{c}$ ), anti strange ( $\bar{s}$ ), antitop ( $\bar{t}$ ), and antibottom ( $\bar{b}$ ). Antiquarks can be found in both antibaryons and mesons but never in isolation. (B7)

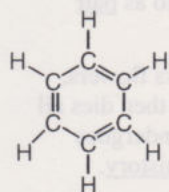
**aqueous\*** (aq) An adjective that indicates that the chemical species it refers to is dissolved in water, e.g.  $H^+(aq)$ . An aqueous solution is one in which water is the solvent. (B6)

**arc second**  $\frac{1}{3600}$  of a degree. One degree consists of 60 arc minutes, and one arc minute consists of 60 arc seconds. (B11)

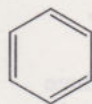
**Archaea\*** A domain consisting of prokaryote organisms; there are two such domains, the other being Bacteria. (B4)

**area\*** A measure of the size of the surface of an object. The areas of squares and rectangles are found by multiplying their length by their width. In SI units, area is measured in square metres ( $m^2$ ). (B1)

**aromatic compound\*** In the context of S103, an aromatic compound is defined as a derivative of benzene,  $C_6H_6$ :



This is sometimes written as



where the element symbols and the bonds to hydrogen are not shown. The largest source of aromatic compounds is crude oil. A number of these compounds have a pleasant odour, hence the name. (B8)

**arthropod** A member of the phylum Arthropoda, the largest phylum in the animal kingdom. Arthropods include insects, spiders and crustaceans. (B4)

**asexual reproduction\*** A form of reproduction in which an individual organism produces offspring without combining part of its genetic material with part of that of another individual. Compare with sexual reproduction. (B4)

**assimilated material\*** Material that is consumed and either retained as biomass or used in respiration. It excludes material that is eliminated as faeces or regurgitated. (B4, A7.1)

**asteroid** See minor planet.

**asthenosphere\*** The weaker region of the Earth below the lithosphere, within the mantle. (B3)

**atmosphere\*** The complete layer of air that surrounds a planet, such as the Earth. The lowest two zones of the Earth's atmosphere are the troposphere and stratosphere. (B2)

**atom\*** The smallest entity of a chemical element. Atoms are roughly  $10^{-10}$  m across. (B2)

**atomic mass** See relative atomic mass.

**atomic nucleus\*** (plural: nuclei) The core of an atom. It contains nearly all of the atomic mass and is positively charged. With the exception of the hydrogen nucleus,  $^1H$ , which is a single proton, nuclei consist of protons and neutrons. (B6)

**atomic number Z\*** The number of protons within the nucleus of an atom; it is also equal to the number of electrons in the neutral atom. Each chemical element has a unique, characteristic atomic number. (B6)

**atomic spectrum\*** An emission spectrum or an absorption spectrum characteristic of a particular atom. (B7)

**atomic theory\*** The theory that takes all matter to be composed of the atoms of about 100 different chemical elements. It was first proposed by John Dalton (1803). He regarded the atoms of any particular element as indestructible and identical in mass (both since shown to be incorrect), and believed that chemical compounds were formed by the combination of the atoms of different chemical elements in simple ratios. (B6)

**ATP\*** A molecule consisting of an organic part — base plus sugar — and a short chain of three phosphate groups. ATP is the molecular link between energy-requiring reactions and energy-releasing reactions in the cell. It is formed from ADP and  $P_i$  in the coupling of ATP synthesis to energy-releasing reactions. Conversely, ATP breakdown to ADP and  $P_i$  is coupled to energy-requiring reactions. (B9)

**ATP synthase\*** A membrane-bound protein which has a central channel for the passage of protons, and which catalyses the reaction:  $ADP + P_i \rightarrow ATP$ . The passage of protons through the channel, down their concentration gradient, provides energy for the oxidative phosphorylation reaction. ATP synthase is present in the inner membrane of both mitochondria and chloroplasts. (B9)

**attributes of life\*** The three qualities possessed by all living organisms, i.e. reproduction, growth and metabolism. (B4)

**autosome\*** A chromosome other than a sex chromosome; autosomes are paired in a diploid cell. (B4)

**autotroph\*** An organism that makes its own carbon-based material starting with carbon dioxide. An autotroph is also known as a producer. Almost all plants



are autotrophs; they convert carbon dioxide into carbon-based material by photosynthesis. Compare with heterotroph and consumer. (B4)

**Avogadro constant\*** The number of formula units that are present in one mole of a pure chemical substance. It has the value  $6.02 \times 10^{23} \text{ mol}^{-1}$ . (B6)

**Avogadro's hypothesis\*** (law) Under the same conditions of temperature and pressure, equal volumes of different gases contain the same number of molecules. (B6)

**axial tilt\*** The angle between the axis of rotation of a planet, and the line perpendicular to the plane of the planet's orbit around the Sun. (B2)

**axis** (of a graph) A horizontal or vertical reference line which carries a scale, used to locate points on a graph. Graphs have both horizontal and vertical axes. (B1)

**axis of rotation\*** An imaginary line through an object, around which the object rotates. (B2) The axis of rotation of a pair of plates is the axis that passes through the centre of the Earth, around which one lithospheric plate rotates relative to another. (B3, A13.3)

**Bacteria\*** A domain consisting of prokaryote organisms; there are two such domains, the other being Archaea. (B4)

**balanced chemical equation\*** See chemical equation.

**balanced polymorphism\*** The polymorphism that exists within a population as a result of a balance between opposing selection forces. One example of balanced polymorphism is the balanced occurrence — in an area of endemic malaria — of the alleles  $Hb^S$  and  $Hb^A$ , and the associated sickle-cell phenotype and normal red blood cell phenotype. (B9)

**'ball-and-stick' representation\*** A model in which each ball represents an atom and each stick represents the chemical bond that holds the atoms together. The colours of the spheres distinguish the types of atom. (B2)

**bar\*** A unit of pressure. 1 bar is approximately equal to the atmospheric pressure of the Earth at sea-level. (B2)

**baryon\*** A subatomic particle composed of three quarks. The matter counterpart of an antibaryon. A type of hadron. Examples include the proton and the neutron. (B7)

**basalt\*** A dark-coloured, fine-grained igneous rock, formed as a result of the rapid cooling of basaltic magma at the Earth's surface. Basalt and its intrusive equivalent, gabbro, are the principal components of the oceanic crust. (B3) It contains the minerals pyroxene, plagioclase feldspar, and sometimes olivine. (B10)

**base\*** (biology) A general name for the nitrogen-containing organic group present in nucleic acids. There are four different bases in DNA: adenine (A), guanine (G), cytosine (C) and thymine (T). In RNA, thymine is replaced by uracil (U). (B9)

**base** (chemistry) A substance that can neutralize an acid by forming a salt; if a base dissolves in water, it forms aqueous hydroxide ions. (B6) A basic solution is one in

which the hydrogen ion concentration is less than  $1.0 \times 10^{-7} \text{ mol litre}^{-1}$  at 25 °C. See also neutralization, pH scale. (B8)

**base-pairing\*** Bases are paired according to precise rules, between complementary strands of DNA, between the template strand of DNA and mRNA (during transcription), and between an mRNA codon and an anticodon sequence of tRNA (during translation). The rules are that adenine pairs with thymine (or uracil in RNA) and cytosine pairs with guanine. This is summarized in symbols in Table 1.

Table 1 Base-pairing rules in DNA, and during transcription and translation.

DNA base	DNA base	mRNA base	tRNA base
A	T	A	U
G	C	G	C
C	G	C	G
T	A	U	A

(B9)

**basic hydroxide\*** A chemical compound, such as NaOH or  $\text{Ca}(\text{OH})_2$ , whose formula contains one or more hydroxide groups, and which dissolves in water to form aqueous hydroxide ions. If the basic hydroxide is sufficiently soluble in water, the resulting solution will be alkaline: it will turn red litmus blue. (B6)

**bed\*** A layer of sedimentary rock within the Earth's crust (the plural, beds, is synonymous with strata). (B3)

**Benioff zone** See Wadati–Benioff zone.

**best-fit line\*** A line (usually a straight line) drawn on a graph which gives the best approximation to the average trend of the data, and passes through, or close to, the data points plotted on the graph. (B3)

**beta-minus decay\*** ( $\beta^-$ -decay) A type of radioactive decay in which a neutron is converted into a proton with the emission of an electron and an electron antineutrino. At a deeper level this may be understood as resulting from the conversion of a down quark into an up quark. All beta-decays are examples of processes that depend on the weak interaction. Compare with beta-plus decay. (B7)

**beta-particle** ( $\beta$ -particle) A fast-moving electron emitted during a particular type of radioactive decay known as  $\beta$ -decay. Being electrons,  $\beta$ -particles carry a negative charge. (B6)  $\beta$ -particles are, in fact, only emitted in beta-minus decay. In beta-plus decay a positively charged particle (a positron or antielectron) is emitted instead. (B7)

**beta-plus decay\*** ( $\beta^+$ -decay) A type of radioactive decay in which a proton is converted into a neutron with the emission of a positron and an electron neutrino. At a deeper level this may be understood as resulting from the conversion of an up quark into a down quark. All beta-decays are examples of processes that depend on the weak interaction. Compare with beta-minus decay. (B7)

**biennial** A plant that grows from seed one year, flowers and produces seeds of the next generation the following year, and then dies. A biennial therefore undergoes



reproduction once in the course of its life history. Compare with annual and perennial. (B4)

**Big Bang\*** The event that marks the creation of time and space. The beginning of the Universe. (B11)

**binary compound\*** A chemical compound composed of just two chemical elements. (B6)

**binding site** The site on the surface of a globular protein, such as a receptor protein or antibody, to which a specific molecule binds, such as a hormone or pathogen, respectively. Only molecules with the correct functional groups and geometry will fit. Compare with active site. (B9)

**biodiversity\*** A term used to encompass all the species living on Earth, or a specified part of it, at any time; sometimes used to encompass ecosystem diversity as well. (B4)

**biogeochemical cycle\*** The global transfer of a chemical element (such as carbon) between living organisms (biological cycle) and the non-living environment (such as soil, water, rocks and air) (geochemical cycle). (B2)

**biological community\*** Those species that interact in a particular area. (B4)

**biological cycle\*** Part of a biogeochemical cycle in which living organisms are directly involved. (B2)

**biological pump\*** The transfer of carbon from surface waters to the deep ocean through phytoplankton production followed by downward drift of organic debris. The term 'pump' is used to convey the fact that this process results in a net transfer of carbon dioxide from the surface ocean to the deep ocean. (B2)

**biomass\*** The mass of all of the living organisms forming a given population or inhabiting a given region. It is usually expressed as the mass of dry material, but may also be expressed as the mass of carbon in that dry material. (B2) Biomass is also used to refer to the matter of which an individual organism is composed. In ecology, biomass is often expressed in terms of the chemical energy stored in the organisms. (B4, A7.1)

**biopolymer\*** A polymer found in biological material; a naturally occurring polymer. The commonest are the proteins, polysaccharides and nucleic acids. (B9)

**biosphere\*** The part of the Earth that is capable of supporting life. (B3)

**biostratigraphic column\*** The division of the stratigraphic column into a succession of zones, each of which represents a different time interval and is characterized by one or more particular fossil species. See also stratigraphy. (B10)

**biosynthesis\*** The cellular process of combining small organic molecules to make the complex molecules found in living organisms. Different substances are made by different biosynthetic pathways. All biosynthetic pathways are energy-requiring. Biosynthesis and catabolism together constitute metabolism. (B9)

**biota** The animal and plant life that characterizes a particular region. (B4)

**bivalent\*** The paired homologous chromosomes, at prophase I of meiosis, each of which is composed of two chromatids, giving a total of four strands. (B9, A8.4)

**bivalve\*** A member of a class of molluscs that has a shell with two valves. In most bivalves, one valve is the mirror image of the other. (B10)

**black smoker** A black plume of tiny metal-rich mineral grains and hot water formed when hydrothermal fluid discharges into cold seawater at a mid-ocean ridge. (B3, A12.1)

**black-body radiation** The electromagnetic radiation that comprises a black-body spectrum. (B11)

**black-body spectrum\*** A continuous spectrum emitted by a 'black' object, i.e. an object that absorbs all of the radiation incident on it. All black-body spectra have a similar characteristic shape whose mean photon energy is uniquely related to the temperature of the object (or equivalently the temperature of the radiation) by  $E_{\text{ph,mean}} = 2.7kT$  where  $k$  is the Boltzmann constant. Also known as thermal spectrum. (B11)

**blue-shift\*** ( $z$ ) The shift in the spectrum of a source of electromagnetic radiation that is approaching the observer. Quantified by the equation,  $z = \frac{\Delta\lambda}{\lambda_0}$  where  $\Delta\lambda$

is the shift in wavelength of a particular feature in the spectrum and  $\lambda_0$  is the original (or rest) wavelength of the same feature. A blue-shift corresponds to a shortening of the emitted wavelength. See also red-shift. (B11)

**BODMAS\*** A mnemonic that tells you the order in which you must carry out the operations in calculations. Brackets have precedence over all other operations (i.e. complete any operations inside brackets first), followed by the Divisions and Multiplications, and finally the Additions and Subtractions. However, in any part of a calculation that involves just divisions and multiplications, or just additions and subtractions, you must work from left to right, i.e. in the order in which the calculation is written. (B1) *SGSG* uses the mnemonic BIDMAS, where 'I' stands for 'indices', an alternative term for 'powers'. When doing a calculation involving indices, you need to work these out before doing the 'DMAS' operations.

**body fossil\*** A fossil of the bodily remains of an organism (e.g. a shell, bone or leaf), or its impression in the enclosing rock. Contrast trace fossil. (B10)

**body wave\*** A seismic wave that travels through the interior of the Earth. There are two types of body wave: a P wave and an S wave. (B3)



**Bohr model of the atom\*** A model of the atom developed by Niels Bohr. It was a 'half-way house' between the Rutherford model of the atom and the Schrödinger model of the atom. In the model, electrons were envisaged as orbiting an atomic nucleus at certain specific radii with specific energies, between which quantum jumps were allowed. (B7)

**boiling temperature\*** The temperature at which a liquid boils, i.e. bubbles up and turns into a gas. This temperature depends on various factors, and the *normal* boiling temperature is the temperature at which the liquid boils at sea-level under normal atmospheric conditions. (These conditions are defined in Block 2.) On the Celsius scale the *normal* boiling temperature of water is 100 °C. (B1)

**Boltzmann constant (*k*)** A fundamental constant of atomic physics which relates the energy of a system of particles to its temperature. The value of the Boltzmann constant is  $k = 8.6 \times 10^{-5} \text{ eV K}^{-1}$  or  $k = 1.4 \times 10^{-23} \text{ J K}^{-1}$  in alternative units. (B11)

**bond\*** See chemical bond.

**boson** A particle which is exchanged in one of the four fundamental interactions, or one of the unified interactions. See photon, gluon, W boson, Z boson, graviton, Higgs boson, X boson. (B11)

**bottom quark (b)** A fundamental particle with electric charge  $-\frac{1}{3}e$ . More massive than either the charm quark or strange quark. (B7)

**bound-bound absorption** A process in which an atom (or other quantum system) absorbs a photon of electromagnetic radiation and so makes a transition from one bound quantum state to another bound quantum state of higher energy. (B11)

**bound-bound emission** A process in which an atom (or other quantum system) emits a photon of electromagnetic radiation and so makes a transition from one bound quantum state to another bound quantum state of lower energy. (B11)

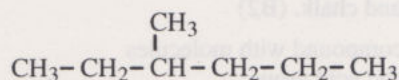
**bound-free absorption** A process in which an atom (or other quantum system) absorbs a photon of electromagnetic radiation and so makes a transition from a bound quantum state to a quantum state in which an electron is freed from the atom. Also referred to as ionization. (B11)

**Boyle's law\*** At constant temperature, the pressure of a fixed mass of gas multiplied by its volume is a constant. (B6)

**brachiopod\*** A member of the marine phylum Brachiopoda, possessing a shell with two valves of dissimilar shape and size. Brachiopods were much more abundant in the Palaeozoic and Mesozoic than today. (B10, A3.1)

**bracketing\*** The procedure that allows the age of a rock to be established from its relationship with other rocks of known absolute age. For example a sedimentary rock layer, underlain by a lava flow with a radiometric age of 100 Ma and cut by a dyke with a radiometric age of 75 Ma, must have an age of between 75 Ma and 100 Ma. See also radiometric dating. (B10)

**branched-chain alkane\*** An alkane in which one or more hydrocarbon groups are bonded to carbon atoms in the main chain giving a branched chain, e.g.



Contrast linear-chain alkane. (B8)

**branched-chain hydrocarbon** A hydrocarbon that has a main chain of carbon atoms with other carbons attached as branches (see branched-chain alkane). (B8)

**breeding episode** An occasion on which reproduction is attempted and possibly achieved. (B4)

**brightness\* (*F*)** The power per unit area of light (or other electromagnetic radiation) received from a source. It is related to the luminosity of the source *L* and its distance away *r* by the equation  $F = \frac{L}{4\pi r^2}$ . Measured in the SI unit of  $\text{W m}^{-2}$ . The brightness of a source is also referred to as its flux. (B11)

**brittle deformation\*** (of rocks) The fracturing of rocks in response to forces of compression or tension accompanying earth movements. (B10)

**calcite** A crystalline form of calcium carbonate. The shells of many marine organisms are composed of calcite, and the remains of these may accumulate on the sea floor and eventually may form limestone. (B3)

**Calvin cycle\*** The cycle of reactions that constitute the dark reactions of photosynthesis, in which carbon dioxide is reduced and converted into sugars in the stroma of the chloroplast. The cycle is named after Melvin Calvin, its principal discoverer. (B9)

**Cambrian explosion\*** A sudden, major burst of evolution, around the start of the Cambrian Period, when a wide variety of animal phyla, especially those with hard, mineralized parts, first appear in the fossil record. (B10)

**Cannizzaro's principle** The proposal, advanced by Stanislaw Cannizzaro in 1858, that the mass of one atom of an element should be regarded as the smallest mass of that element to be found in any molecule containing it. (B6)

**carbohydrate** Collective term for sugars and polysaccharides. (B9)

**carbon cycle\*** The biogeochemical cycle of the element carbon. (B2)

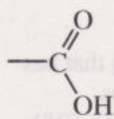
**carbon dioxide** A chemical compound made up of molecules consisting of one carbon atom chemically bonded to two oxygen atoms. The molecule is represented as  $\text{CO}_2$ , where C denotes a carbon atom, O an oxygen atom, and the subscript 2 that there are two oxygen atoms in the molecule. Carbon dioxide is a gas at normal atmospheric temperatures and makes up about 0.036% of the Earth's atmosphere. (B2)

**carbonate\*** A mineral containing the  $\text{CO}_3$  carbonate group, e.g. calcite,  $\text{CaCO}_3$  (calcium carbonate). (B10)



**carbonate rocks\*** Rocks containing carbon in the form of carbonate compounds, the most common being calcium carbonate. Common forms of calcium carbonate rocks are limestone and chalk. (B2)

**carboxylic acid** A compound with molecules containing a carboxylic acid group:



or  $\text{—COOH}$ . Carboxylic acids have the general formula  $\text{R—COOH}$ . (B8)

**carnivore\*** An organism that obtains its carbon-based materials by consuming living or recently killed animals, either in whole or in part, i.e. a type of heterotroph. Compare with decomposer, detritivore, herbivore. (B4)

**carrying capacity (K)\*** The maximum stable size of a population in a particular habitat. Compare with intrinsic rate of natural increase. (B4)

**catabolism\*** The breaking down of a molecule into smaller molecules, usually involving the release of energy. Catabolism may be aerobic or anaerobic. There are many different aerobic catabolic pathways but these all lead into the central pathway. Catabolism and biosynthesis together constitute metabolism. (B9)

**catalyst\*** A substance that speeds up a chemical reaction, by providing an alternative path with a lower energy barrier. Catalysts have no effect on the equilibrium composition; and are not consumed in the reaction. In living organisms, all enzymes are catalysts. (B8)

**catalytic cracking\*** The use of a catalyst to break down the molecules of the high boiling temperature fractions of crude oil (long-chain alkanes) to alkenes and alkanes of lower relative molecular mass. (B8)

**catalytic reforming\*** The process by which linear-chain hydrocarbons are converted, with the aid of a catalyst, into aromatic compounds or branched-chain alkanes. (B8)

**catastrophism\*** The doctrine that interpreted sudden changes seen in the geological record to be the result of catastrophes of global proportions, often inferred to have been of divine origin. Contrast with the principle of uniformitarianism. (B10)

**cell\*** The smallest unit of an organism that is capable of showing the three attributes of life. The three main components of a eukaryote cell are the cell membrane, the cytoplasm and the nucleus. A prokaryote cell does not possess a nucleus. A multicellular organism consists of more than one cell (usually many more). A specialized cell is one which specializes in the performance of a particular function. (B4)

**cell cycle\*** The repeated alternation of cell growth and cell division characteristic of all organisms. (B4)

**cell division\*** The part of the cell cycle in which a single cell splits into two progeny cells; cell division follows mitosis and entails the production of a new cell membrane which divides the original cell's cytoplasm between the two progeny cells. The term 'cell division' is sometimes used loosely to include mitosis. (B4)

**cell growth** The part of the cell cycle in which a cell increases in size prior to cell division; it comprises three phases: growth I, replication (of DNA) and growth II. (B4)

**cell membrane\*** The structure that separates the rest of a cell from the cell's external environment. The cell membrane is selectively permeable in that it can, to some extent, control which substances pass through it. (B4)

**cell wall\*** The structure that occurs outside the cell membrane of the cells of most plants, fungi and bacteria, and helps to maintain a rigid cell shape. In plants, it is made of fibres of cellulose which are 'glued together'. (B9)

**cellulose** An unbranched polymer of glucose. It is the major structural polysaccharide of plant cell walls. (B9)

**Celsius scale\*** A scale used for measuring temperature. The normal freezing temperature of water on this scale is defined as  $0^{\circ}\text{C}$  (zero degrees Celsius) and the normal boiling temperature of water as  $100^{\circ}\text{C}$  (one hundred degrees Celsius). (B1)

**cementation\*** The process of mineral growth in the spaces between the grains of a sediment or sedimentary rock. The resulting cement (commonly quartz or calcite) holds the grains together. Cementation is very effective in lithification of sandstones. (B10)

**Cenozoic\*** The youngest era of the Phanerozoic, consisting of the Neogene and Palaeogene Periods (the Tertiary sub-Era) and the Quaternary Period. It spans from 65 Ma ago to the present day. (B10)

**centi\*** A prefix to a unit, which means 'one-hundredth'; for example, a centimetre is one-hundredth of a metre,  $1\text{ cm} = \frac{1}{100}\text{ m}$ . (B1)

**central dogma** The flow of information from DNA to RNA to polypeptide. (B9)

**central pathway** The pathway of glucose oxidation (glycolysis, link reaction, TCA cycle and electron transport coupled to oxidative phosphorylation), which is central to all metabolism in the cell. (B9)

**centromere\*** The point of attachment of one chromatid to its partner to make up a single chromosome. (B4)

**CERN** The European laboratory for particle physics near Geneva. (B11)

**character\*** A term used in biology to mean a characteristic or trait of an organism or species. (B4)

**charge** See electric charge.

**Charles' law\*** At constant pressure, the volume of a fixed mass of gas divided by its absolute temperature is a constant. (B6)

**charm quark (c)** A fundamental particle with electric charge  $+\frac{2}{3}e$ . More massive than either the up quark or down quark. (B7)

**chemical bond\*** The means by which atoms are attached to each other. For example, in a water molecule an oxygen atom is attached to each of two hydrogen atoms by a chemical bond. (B2)



**chemical bonding\*** The forces that hold atoms together in chemical compounds. The forces are described in different ways, depending upon the type of compound that is formed. Atoms in molecular substances are held together by covalent bonds; ions in ionic compounds by the attraction between ions of opposite electric charge. Weaker types of bonding such as London interactions and hydrogen bonds also occur. (B8)

**chemical composition\*** The masses of the constituent chemical elements contained in a sample of a chemical compound, expressed as percentages of the total mass of the sample. (B6)

**chemical compound\*** A substance that is made up of more than one chemical element, where an atom of one element is attached to an atom of another element by a chemical bond. (B2) The atoms of the different chemical elements are bound together in a fixed ratio, which is characteristic of the substance. (B6)

**chemical element\*** A substance that consists of only one type of atom. For example, the chemical element copper is made only of copper atoms. (B2) A chemical element cannot be broken down into simpler constituents by using chemical reactions. All the atoms in a sample of a chemical element have the same atomic number. (B6)

**chemical energy\*** The form of energy that changes in a chemical reaction. It is a form of internal energy. The rearrangement of atoms that takes place in a chemical reaction leads to changes in the potential energy of the atoms, and this is responsible for the change in chemical energy. (B5)

**chemical equation\*** A statement that uses chemical symbols for the chemical elements and represents the conversion of reactants into products in a chemical reaction. The equation must be balanced: the same numbers of each type of atom, and the same total electric charge must be present on each side of the equation. (B6)

**chemical equilibrium\*** A chemical system at a constant temperature in which two opposed chemical processes are proceeding at equal rates. Because the rates of the opposed processes are equal, the system appears to undergo no change. (B8)

**chemical formula\*** A representation of a chemical substance that uses chemical symbols to denote the constituent atoms, and subscripts to indicate the relative numbers of atoms of each type. For example, water is represented by the formula  $H_2O$ . (B6)

**chemical group\*** A particular numerical combination of atoms that is found in the formulae of many different chemical substances. For example, the nitrate group,  $NO_3$ , is found in nitric acid,  $HNO_3$ , and in calcium dinitrate,  $Ca(NO_3)_2$ . (B6)

**chemical periodicity\*** A phenomenon that Mendeléev called the *Periodic Law*. The modern version states that the chemical elements, when placed in order of atomic number, display an evident periodicity of properties: that is, similar elements occur at regular intervals. (B6)

**chemical reaction\*** A process in which a substance, or substances (the reactant), is transformed into a different substance, or substances (the product). Chemical reactions nearly always involve the rearrangement of atoms. (B2) The essential feature of a chemical reaction

is that the atoms in the reactants and products, or more precisely their nuclei and electrons, are conserved; they merely undergo rearrangement. This distinguishes a chemical reaction from a nuclear reaction. (B6)

**chemical symbol** The letters used to symbolize a chemical element, or an atom of the element; for example, O for oxygen, Cu for copper. (B6)

**chemical weathering\*** The breakdown of rocks at the Earth's surface by the chemical action of acidic rainwater, e.g. the dissolution of limestones and the decomposition of feldspars to clay minerals. Contrast physical weathering. (B10)

**chemiosmotic hypothesis\*** An hypothesis proposed to explain how electron transport and ATP synthesis are linked by a proton gradient across the inner mitochondrial membrane. A proton gradient also occurs across the inner membrane of the chloroplast. (B9)

**chloroplast\*** Plant cell organelle in which photosynthesis takes place. The layers of membranes within chloroplasts contain chlorophyll and are the site of the light reactions of photosynthesis. The dark reactions of photosynthesis occur in the stroma which surrounds the internal chloroplast membranes. (Not all plant cells contain chloroplasts.) (B4, B9)

**chromatid\*** One of a pair of identical DNA molecules (with associated protein molecules). Between replication and the anaphase stage of mitosis, each chromosome in a cell consists of two chromatids joined together at a centromere. (B4)

**chromosome\*** A structure composed of the genetic material of a cell (the DNA) and protein molecules. A chromosome may be an autosome or a sex chromosome. During the replication phase of the cell cycle, the DNA in each chromosome is copied so that each of the progeny cells eventually contains an identical set of chromosomes (and hence genetic material) to that of the parent cell. In a eukaryote, chromosomes are normally contained within the nucleus. (B4)

**chromosome mutation\*** A change in the number or structure of chromosomes. Down's syndrome in humans, which is associated with an extra chromosome 21 in each cell of the body, is an example of a chromosome mutation. (B9)

**circle** A closed curve that is everywhere the same distance from the point at its centre. This distance is known as the radius of the circle. (B3)

**citrate** A 6C intermediate in the TCA cycle. It is formed when oxaloacetate (a 4C intermediate in the cycle) reacts with acetyl (2C) in the form of acetyl CoA. (B9)

**class** The level of taxonomic classification between phylum and order. For example, the class Mammalia (mammals) is part of the phylum Chordata (mostly animals with backbones) and comprises several orders, including Carnivora (in which cats and dogs are classified) and Primates (in which humans are classified). (B4)

**class of (organic) compounds\*** A series of compounds with molecules that contain the same functional group; for example, the alcohols all contain an alcohol group —OH. (B8)



**cleavage\*** (in minerals) Planes of weakness within a mineral along which it tends to break. The planes are related to the arrangement of atoms in the mineral's structure. (B10, A4.2)

**cleavage** (in rocks) The property of a rock that enables it to split along parallel, planar surfaces. It is developed by the alignment of mica under pressure during low-grade regional metamorphism. (B10)

**climate** The long-term prevalent weather conditions in a region. (B2)

**climate model\*** A mathematical model that can be used to calculate aspects of climate, for example, the global mean surface temperature (GMST). (B2)

**clone\*** Progeny cells that contain DNA identical to that of the parent cell that divided to produce them are said to be clones of the parent cell and also of one another; where such a cell divides repeatedly to produce a new multicellular organism, that organism is often loosely referred to as a clone of the organism from which the original cell was taken. (B4)

**closed Universe\*** A model of the Universe in which the density of matter is sufficient eventually to halt the expansion and cause a subsequent collapse into a presumed big crunch. A closed Universe is finite in size at all times. In a closed Universe, the actual density is greater than the critical density. (B11)

**cluster of galaxies** An assemblage of galaxies that are bound together by their mutual gravitational force of attraction. The Local Group of galaxies is a cluster of galaxies that includes the Galaxy and the Andromeda Galaxy. (B11)

**coal** An organic sedimentary rock formed by lithification of plant material. Coal forms when decomposition of plant material is incomplete, usually in areas with high rainfall. If given enough time (millions of years) combined with burial under other sediment, such matter can turn into coal. (B3)

**COBE** The Cosmic Background Explorer satellite which measured the cosmic microwave background radiation. (B11)

**codominance\*** A situation where a heterozygote shows the phenotype of both alleles of a gene. (B9)

**codon\*** A specific sequence of three bases (of DNA or mRNA) coding for a particular amino acid. The sequence of codons determines the sequence of amino acids in a polypeptide. This relationship between codon and amino acid forms the basis of the genetic code. During translation, each mRNA codon binds to a specific tRNA anticodon. (B9)

**coefficient\*** The number that precedes a chemical formula in a balanced chemical equation. Where no number is recorded, it is assumed to be 1. (B6)

**coenzyme\*** A small organic molecule that works with an enzyme in some reactions. It binds to the active site of the enzyme, and transfers small groups of atoms (e.g. 2H, acetyl) to the substrate — or else picks up small groups of atoms as they are removed from the substrate. Examples are NAD, NADP and coenzyme A. (B9)

**coenzyme A\*** A coenzyme used in the link reaction; here it transfers the 2C acetyl group, to the 4C oxaloacetate (OAA) of the TCA cycle to form 6C citrate. (B9)

**coevolution\*** Evolution occurring simultaneously in different species, in which each becomes adapted as a result of the selection pressures each species imposes on the other. A striking example is parasite and host species. (B9)

**collagen** A fibrous protein, one molecule of which is composed of three fibres wound round each other to form a helix. It is major component of the extracellular matrix. (B9)

**colour charge\*** A property possessed by quarks (and antiquarks) and gluons. It plays a role in quantum chromodynamics, equivalent to that of electric charge in quantum electrodynamics. Quarks can possess any one of red, green or blue colour charge, antiquarks can possess any one of antired, antigreen or antiblue colour charge. Like colour charges repel each other, unlike colour charges attract each other, via the strong interaction. Only colour neutral particles can exist in isolation, all hadrons therefore have a net colour charge of zero. Hence baryons contain three quarks each with a different colour charge (one red quark, one blue quark, one green quark), antibaryons contain three antiquarks each with a different colour charge (one antired antiquark, one antiblue antiquark and one antigreen antiquark), and mesons contain a quark and an antiquark with opposite colour charges (either one red quark and one antired antiquark, or one blue quark and one antiblue antiquark, or one green quark and one antigreen antiquark). (B11)

**comet\*** A small body in orbit around the Sun. Most comets range far and wide across the Solar System. A comet consists largely of icy materials that evaporate to give rise to huge tails when the comet is near the Sun. (B3)

**community** See biological community.

**compaction\*** The process of packing sediment grains more closely together during burial due to the weight of overlying layers of sediment. Compaction is very effective in expelling water from muds. (B10)

**complementary bases\*** Bases that bind together in pairs between the two polynucleotide strands of DNA, between a strand of DNA and RNA during transcription, and between mRNA and tRNA during translation. In DNA there are two pairs of complementary bases: T (thymine) pairs with A (adenine); C (cytosine) pairs with G (guanine). In RNA the two complementary base pairs are: U (uracil) with A, and C with G. (B9)

**component of fitness\*** A partial measure of the fitness of an organism; for example, survival to the age at which reproduction can occur, and number of eggs produced, are both components of fitness in birds. (B4)

**compound** See chemical compound.

**compression** An object or material is in a state of compression when a force, or a pressure, acts on it in such a way as to decrease its volume. (B10)

**computer model\*** A mathematical model that uses a computer to perform the calculations. (B2)

**concentration\*** A measure of the amount of solute (often a solid) dissolved in a specific volume of solution. Units relate to the mass (g or kg) or number of moles of solute in a volume of solution, e.g. g litre<sup>-1</sup> or mol litre<sup>-1</sup>. (B8)



**condensation\*** The process whereby a substance changes from the gaseous state to the liquid state, e.g. water changes from water vapour to liquid water. (B1)

**condensation polymer\*** A polymer that is formed by the linking of monomer molecules by means of a condensation reaction. (B8)

**condensation reaction\*** The reaction of two molecules to form a bond between them, usually with the simultaneous formation of a small molecule such as water (H<sub>2</sub>O), ammonia (NH<sub>3</sub>), or hydrogen chloride (HCl). An example is the reaction between a carboxylic acid (e.g. acetic acid) and an alcohol (e.g. ethanol) to form an ester and water. (B8)

**conduction\*** (of heat) The transfer of energy through a substance from a region of higher temperature to a region of lower temperature, without any movement or flow of the substance. (B2)

**conductor** See electrical conductor.

**confinement\*** The process by which quarks and antiquarks remain locked up inside hadrons. (B11)

**conglomerate\*** A sedimentary rock containing large, often rounded, pebbles or other fragments. (B10)

**conservation of electric charge\*** This law states that, in an isolated system, the total electric charge cannot change. (B6)

**conservation of energy\*** One of the most important laws in science. In any process, the total amount of energy is always constant. Energy cannot be created or destroyed. (B5)

**conservation of mass\*** During any chemical reaction, there is no detectable change in mass: the mass of the reactants is equal to that of the products. (B6)

**constant of proportionality\*** If two quantities are proportional to each other, for example  $y \propto x$ , then we can write  $y = kx$ , where  $k$  is the constant of proportionality. (B5)

**consumer\*** An organism that obtains its carbon-based materials by consuming another organism either in whole or in part, either living or dead. A consumer is also known as a heterotroph. Compare with producer. (B4, A7.1)

**contact metamorphism\*** The metamorphism of rocks baked by an invading body of magma. Affected zones of rock are narrow or localized in extent and occur at relatively shallow depth. Mineral growth is short-lived, thus fine-grained and without textural alignment. Contrast regional metamorphism. (B10)

**continental collision** The process which occurs at a convergent plate boundary between two plates, both with continental lithosphere. The two continents collide because they are not dense enough for subduction to occur. The collision produces a broad region of shallow-focus earthquake activity, metamorphism and growth of a mountain belt along the length of the plate boundary. (B3)

**continental drift\*** The theory, put forward by Alfred Wegener, that proposed that the continents have moved over the Earth through geological time. (B3)

**continental rise\*** The area of the ocean floor that marks the transition between the continental slope and

the abyssal plain. The average gradient of the continental rise is about 0.5°. The continental rise is typically several hundred kilometres wide and generally contains the boundary between continental and oceanic crust. (B3)

**continental shelf\*** The area of the ocean floor bordering the continental landmasses at a depth of 200 m or less below the sea surface. The continental shelf has an average gradient of about 0.1°. (B3)

**continental slope\*** The area of the ocean floor extending from the edge of the continental shelf to the start of the continental rise. The continental slope has an average gradient of about 4°. (B3)

**continuous spectrum\*** A spectrum consisting of light (or other electromagnetic radiation) of all colours (or all energies, wavelengths or frequencies). The spectrum of white light from a tungsten filament light bulb has a continuous spectrum. (B7)

**continuous variation\*** Variations in a phenotypic character that are smooth and continuous rather than distinct and abrupt. An example is height in humans. The development of the phenotype of continuously varying characters is due to the joint action of several genes, each of which has, individually, a very small effect on the phenotype, and is also influenced by environmental factors. (B9)

**continuum\*** The continuous band of energy levels that exist above the highest bound energy level in an atom. The continuum corresponds to quantum states in which the nucleus and electrons move around independently. (B7)

**contrasting characters\*** Alternative phenotypes, such as purple and white grain colour in maize. (B9)

**convection\*** Motion in a fluid as a consequence of temperature differences. Warmer portions of the fluid rise, transporting energy with them, and cooler portions sink. (B2)

**convergent plate boundary\*** A plate boundary at which two lithospheric plates are moving towards each other. (B3)

**coordinates** (of a point on a graph) The  $x$  and  $y$  values of a point plotted on the  $x$  axis and  $y$  axis of a graph. The coordinates are often written as  $(x, y)$ . (B3)

**coral\*** A member of a group within the marine phylum Cnidaria. Corals secrete a calcium carbonate skeleton below anemone-like soft tissue. (B10, A2.1)

**core\*** The central part of the Earth, composed mainly of iron. The outer core is liquid, the inner core is solid. (B3)

**correlation\*** (in Earth sciences) The matching up of rocks of the same age from one area to another. (B10)

**correlation\*** (mathematical) A relationship between two quantities in which the value of one quantity increases (or decreases) as the value of the other quantity increases (or decreases). (B2)

**cosine\*** A mathematical function relating the lengths of two sides of a right-angled triangle. The cosine of a certain angle is defined as the length of the side of the triangle adjacent to the angle divided by the length of the longest side (hypotenuse) of the triangle. (B7)

**cosmic microwave background\*** (CMB) The black-body radiation that pervades the entire Universe. It is a



relic of the time when matter and electromagnetic radiation were last in thermal equilibrium, about 300 000 years after the Big Bang. The current temperature of the CMB is 2.73 K. (B11)

**coulomb\*** In SI units, the unit of electric charge, with the symbol C. (B5)

**Coulomb constant** The constant of proportionality ( $k_e$ ) in Coulomb's law has a value of  $8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$ . Maxwell's laws of electromagnetism showed that the speed of light  $c$  (and other electromagnetic radiation) is related to the Coulomb constant and the magnetic constant  $k_m$  by  $c^2 = \frac{k_e}{k_m}$ . (B11)

**Coulomb's law\*** Two particles of unlike (or like) charge  $Q_1$  and  $Q_2$ , at rest and separated by a distance  $r$ , will attract (or repel) each other with an electric force that is inversely proportional to the square of their separation, and proportional to the product of the charges,  $F_e = -k_e \frac{Q_1 Q_2}{r^2}$ . The constant  $k_e$  is known as the Coulomb constant. (B11)

**coupling** The influence of one factor upon another. For example, when the solar constant changes then this causes a change in the ice and snow cover of the Earth. The solar constant and ice and snow cover are said to be coupled. Coupling is necessary for feedback to occur. (B2) Another example of coupling is the link between two simultaneous chemical processes in cells; the breakdown of glucose is coupled to the production of ATP, and energy-requiring activities are coupled to the conversion of ATP into ADP and P<sub>i</sub>. (B9)

**covalent bond\*** A type of chemical bond represented by a pair of electrons shared between two atoms. (B8)

**cracking** The thermal decomposition of the molecules of high molecular mass organic compounds to produce molecules of compounds of lower molecular mass. (B8)

**crinoid\*** A member of a class of echinoderms, nicknamed 'sea-lilies', that were much more abundant in the Palaeozoic and Mesozoic than today. (B10, A2.1)

**critical density\*** The density which corresponds to a flat Universe model. If the Hubble constant is currently  $60 \text{ km s}^{-1} \text{ Mpc}^{-1}$ , then the critical density is equivalent to about four protons per cubic metre. (B11)

**cross-bedding\*** A series of thin sedimentary layers inclined to the top and bottom of a sedimentary bed that they lie within. (B10)

**cross-fertilization** The fusion of a male gamete from one plant or animal with a female gamete from another plant or animal of the same species. (B9)

**crossing over\*** The process of recombination involving the exchange of corresponding parts between chromatids of homologous chromosomes by breaking and rejoining; it occurs during prophase I of meiosis and can lead to the recombination of genes and alleles. (B9)

**crust\*** The upper seismic layer of the Earth. The crust has a relatively low density and low seismic wave speeds. It is about 7 km thick under oceans (oceanic crust), and 20–80 km thick (averaging 35 km) under continents (continental crust). Oceanic crust is composed mainly of rocks with composition similar to basalt; continental crust is composed mainly of rocks

with compositions fairly similar to granite. (B3) More accurately, continental crust has a composition closer to diorite. (B10)

**crustal shortening\*** The reduction in lateral extent of parts of the crust due to compression causing deformation of rocks on a regional scale; often associated with mountain-building. (B10)

**Cryptozoic\*** The interval of geological time from the origin of the Earth, 4 600 Ma ago, to the start of the Phanerozoic, 545 Ma ago. The Cryptozoic Eon is often called 'the Precambrian'. (B10)

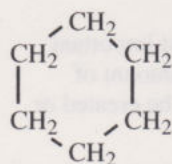
**crystal** A solid with a definite geometric form reflecting the regular arrangement of its constituent atoms. (B3)

**crystallite\*** A small region of a solid polymer, where segments of polymer chains are arranged in a regular manner akin to the regular pattern of molecules in a crystalline solid. (B8)

**crystallization\*** A process, often brought about by cooling or evaporation, in which a solid separates out from its solution in the form of crystals. (B6)

**current** See electric current.

**cycloalkanes\*** Saturated compounds containing only carbon and hydrogen atoms in which the carbon backbone forms a ring structure, e.g. cyclohexane:



(B8)

**cytochrome oxidase** The last carrier in the ETC in the inner mitochondrial membrane which transfers electrons to oxygen. (B9)

**cytoplasm\*** All those parts of a cell enclosed by the cell membrane, other than the nucleus. (B4)

**cytosol\*** The gel-like liquid that remains when rough endoplasmic reticulum and mitochondria (and chloroplasts, in plant cells) and other subcellular structures have been removed. (B9)

**D/P value\*** The number of daughter isotope atoms ( $D$ ) divided by the number of parent isotope atoms ( $P$ ) in a radioactive decay scheme. The  $D/P$  value is related to the time that has elapsed since the decay scheme became a closed system. It progressively increases from an initial value (that may or may not be zero) as the value of  $D$  increases and the value of  $P$  decreases. (B10)

**dark matter** Matter in the Universe detected only by the gravitational force that it produces, i.e. it cannot (at present) be detected by any radiation it emits, reflects, or absorbs. (B3)

**dark reactions\*** The steps of photosynthesis that are concerned with the conversion of carbon dioxide into carbohydrates. They occur in solution in the stroma in a cyclic sequence of reactions which are also called the Calvin cycle. NADP.2H and ATP are used, and these are produced in the light reactions of photosynthesis. (B9)

**daughter nuclide** A nuclide formed as a result of a radioactive decay from a parent nuclide. (B7, A5.1)



**deceleration\*** The slowing down of an object. The term is used to describe the slowing down of the expansion of the Universe, due to the gravitational attraction between all the matter in the Universe. (B11)

**decimal number\*** A number that includes a fraction expressed by digits to the right of a whole number (or zero) and separated from it by a decimal point, for example 12.345. In this example, 12 is a whole number, the 3 denotes three-tenths (3/10), the 4 denotes four-hundredths (4/100), and the 5 denotes five-thousandths (5/1 000). (B1)

**decimal places\*** The number of digits after the decimal point in a decimal number. For example, the number 12.345 is expressed to three decimal places. (B1)

**decimal point\*** This separates the whole number and the fractional part of a decimal number and is represented by a full stop. In the number 12.34, the digits to the left of the decimal point represent a whole number, 12, and the digits to the right of the decimal point each represent a fraction — the 3 denotes 3/10 and the 4 denotes 4/100. (B1)

**decomposer\*** An organism that obtains its carbon-based materials by breaking down dead organisms and the waste products from living organisms outside its own body, and then absorbing the resulting soluble nutrients, i.e. it is a type of heterotroph. A detritivore is sometimes loosely referred to as being a decomposer. (B4, A7.1)

**decomposition\*** The gradual disintegration of dead organic matter. Some decomposition occurs through physical factors such as wind and water, but it is mostly achieved by organisms, often microscopic, which use the organic matter as a source of food. *See* decomposer, detritivore. (B2)

**deep-focus earthquake** An earthquake with a focus at a depth greater than 300 km. (B3)

**deep ocean\*** That part of the ocean that has no contact with the air and receives no solar radiation, and where the water is at a uniform temperature of about  $-1^{\circ}\text{C}$  to  $4^{\circ}\text{C}$ . (B2)

**degassing** The loss of a gas from a solid or liquid. (B2)

**degree\*** (angle) A unit of measurement for an angle, such that there are 360 degrees in a complete turn. The symbol for the degree is  $^{\circ}$ . (B2)

**degree (temperature)** A unit for measurement of temperature, denoted by the symbol  $^{\circ}$ . On the Celsius scale temperatures are measured in degrees Celsius,  $^{\circ}\text{C}$ . There are  $100^{\circ}\text{C}$  between the normal freezing temperature and the normal boiling temperature of water. (B1)

**dehydrogenation\*** An oxidation reaction in which a substance is oxidized by the removal of (usually two) hydrogen atoms from an organic molecule. In the cell, dehydrogenation reactions are catalysed by specific enzymes. (B9)

**delta\*** ( $\Delta$ ) Greek letter that is conventionally used to mean 'the change in'. Thus  $\Delta h$  means the change in height  $h$ , and  $\Delta E_g$  means the change in gravitational energy  $E_g$ . (B5)

**density\*** The mass of a substance per unit volume, i.e.  $\text{density} = \frac{\text{mass}}{\text{volume}}$ . In SI units the unit of density is  $\text{kg/m}^3$ , that is  $\text{kg m}^{-3}$ . (B1)

**density dependent\*** Some factor that has a greater effect when population density is high and a smaller effect when population density is low. If a mortality rate is density dependent, it is high when population numbers are high and low when population numbers are low. Regulating mortality factors are density dependent. (B9, A1.1)

**density independent\*** Some factor whose effects are *not* related to population density. A key mortality factor is usually density independent. (B9, A1.1)

**deoxyribonucleic acid** *See* DNA.

**deoxyribose** A sugar molecule, containing five carbon atoms (in which one hydroxyl in ribose is replaced by a hydrogen atom). One of the components of deoxyribonucleotides — the monomers of DNA. (B9)

**dependent variable** A measured quantity, the value of which depends on the value chosen for another quantity (the independent variable). On a graph, the dependent variable is plotted on the y axis. For example, if an investigator selected children of certain ages and measured their heights, then height would be the dependent variable. (B3)

**desert** (cosmological) The period of time in the history of the Universe, between the end of inflation and the time when electroweak unification broke down, during which no new processes occurred. (B11)

**desiccator\*** A sealed container in which a drying agent is used to dry material that contains water. The drying effect is often enhanced by evacuation of the container. (B6)

**detritivore\*** An organism that obtains its carbon-based materials by eating and breaking down dead organisms and the waste products from living organisms inside its own body, i.e. a type of heterotroph. Compare with decomposer. (B4, A7.1)

**diameter\*** The maximum width of a circle, disc, or sphere. The diameter is twice the radius. (B3)

**diatomic molecules** Molecules composed of two atoms, e.g.  $\text{CO}$ ,  $\text{O}_2$ . (B6)

**diffraction\*** The phenomenon by which light (or any other wave) spreads out when it passes through an aperture whose size is comparable to the wavelength of the light (or other wave). The amount of diffraction increases as either the aperture is made smaller, or as the wavelength is made larger. Diffraction is a characteristic of all types of wave. (B7)

**diffraction grating\*** A device consisting of many parallel, equally spaced apertures, very close together, used to diffract light. A diffraction grating may be characterized by the number of lines per mm, or by the line spacing  $d$ . (B7)

**diffraction orders\*** When a diffraction grating is illuminated with monochromatic light, such as that from a laser, the diffraction pattern will consist of a series of spots spaced either side of the central position. These spots are referred to as diffraction orders. When illuminated with light consisting of a range of



wavelengths, each diffraction order will comprise a spectrum of the light source. (B7)

**diffraction pattern\*** The pattern of light (or other waves) produced when diffraction occurs. (B7)

**dimensionless number** A number which has no unit. For example, the fine structure constant  $\alpha_{\text{em}}$  and  $\pi$ . (B11)

**diorite\*** A coarse-grained igneous rock intermediate in composition between gabbro and granite. The intrusive equivalent of andesite. It usually contains plagioclase feldspar, amphibole and biotite mica, and sometimes pyroxene, alkali feldspar and quartz. (B10)

**diploid\*** A diploid cell is one in which each autosome has a similar-looking partner. Compare with haploid. (B4)

**disaccharide** A molecule formed by the condensation of two monosaccharides. An example is sucrose. (B9)

**disc\*** A flat surface, the perimeter of which is a circle. (B3)

**discontinuous variation\*** Variations or differences in phenotypes that are distinct or abrupt rather than smooth and continuous. An example is the purple and white grain colour of maize. (B9)

**dissolve\*** When a substance, such as salt, is put in a liquid, such as water, it separates into very small particles, which become dispersed in the water so that they can no longer be seen. The salt is said to dissolve in the water to give a solution of salt in water. Some solids do not dissolve in water, but do dissolve in other liquids. Gases can also dissolve in liquids. (B1) A process in which one substance, the solute, which may be a solid, a liquid or a gas, is absorbed by a different liquid substance (e.g. water) to give a homogeneous liquid product which is called a solution. (B6)

**dissolved carbon\*** The various forms in which carbon is found dissolved in natural waters. (B2)

**distillation\*** A process for separating a liquid from a solid or another liquid. The liquid to be separated is first turned into vapour, often by the use of heat; the vapour is then moved to a different and cooler place, where it condenses back into a liquid. (B6)

**divergent plate boundary\*** A plate boundary at which a lithospheric plate moves away from its neighbouring plate. A mid-ocean ridge is a divergent plate boundary. (B3)

**division I and division II of meiosis\*** The two successive divisions that collectively make up the process of meiosis. Division I results in the separation of chromosomes of an homologous pair. Division II results in the separation of the chromatids of each chromosome. (B9, A8.4)

**DNA\*** Abbreviation for deoxyribonucleic acid. The class of molecules that carries the genetic information of organisms and is thus the genetic material. (B4) DNA is a polymer whose monomers are nucleotides, which consist of three component parts joined by covalent bonds: a phosphate group, a sugar (deoxyribose) and a base. There are four different bases in DNA: adenine (A), guanine (G), cytosine (C) and thymine (T). Nucleotides joined together form polynucleotides. Each DNA molecule consists of two polynucleotide chains intertwined to form a characteristic double helix. DNA

molecules are by far the largest known molecules in living organisms; some have relative molecular masses of many billions! DNA carries the genetic information of the cell, coded as a sequence of nucleotides (and hence a sequence of bases). (B9)

**DNA fingerprinting\*** The technique that reveals the unique DNA profiles of individuals which result, in the main, from variation in the number of repeat sequences between individuals. (B9)

**DNA polymerase** The principal enzyme that synthesizes new DNA molecules during DNA replication. (B9)

**DNA replication\*** The synthesis of an exact copy of a DNA molecule. Each single polynucleotide strand is the template on which a new complementary strand is synthesized. Two identical double helices are thereby produced. (B9)

**domain\*** The broadest level in the scheme of taxonomic classification; three domains are recognized: Archaea, Bacteria and Eukarya. (B4)

**dominant\*** Term describing the character that is manifest in a heterozygote; the phenotype of the genotype carrying the dominant allele. (The character that does *not* appear is described as recessive.) (B9)

**Doppler effect\*** The process by which the wavelength of a wave is altered when the source of the wave is moving with respect to the observer. Motion away from an observer causes the wavelength to be perceived as longer than that with which it was emitted, motion towards an observer causes the wavelength to be perceived as shorter than that with which it was emitted. (B11)

**double bond\*** A chemical bond between two atoms that is equivalent to two single bonds; in theories of chemical bonding, it is represented by two shared pairs of electrons. (B8)

**double helix** The configuration of the two polynucleotide strands which are wound round each other to form a molecule of DNA. (B9)

**down quark\*** (d) A fundamental particle with electric charge  $-\frac{1}{3}e$ . One of the constituent particles of both the proton and the neutron. (B7)

**drag force\*** A force acting to slow down the motion of an object. There is a frictional drag force acting on the base of a lithospheric plate as it slides over the underlying asthenosphere. (B3)

**dyke\*** A sheet-like (often near-vertical) body of igneous rock formed when magma is intruded into a crack in pre-existing rocks and which cuts across any layering at a steep angle. A dyke is the solidified content of a channel that transported magma; dykes are often just a few metres wide but can be many kilometres long. (B3) Contrast with sill. (B10)

**earthquake** A sudden violent movement of rocks within the lithosphere of the Earth. (B3)

**earthquake intensity\*** A measure of the size of an earthquake, based on observations of the damage done to buildings, changes in the Earth's surface and the effect on humans. (B3)

**earthquake magnitude\*** A measure of the size of an earthquake, obtained from the amount of energy



released. Earthquake magnitude is measured on the Richter scale. (B3)

**Earth's surface temperature\*** The temperature of the air about 1 m above the ground or sea surface. (B2)

**echinoderm\*** A member of the phylum Echinodermata, a group of entirely marine animals with skeletons composed of many interlocking calcite plates. Among echinoderm groups are sea-urchins (echinoids), crinoids and starfish. (B10)

**echinoid\*** A sea-urchin, member of a class of echinoderms. (B10)

**ecology** The interrelationships between living organisms and their environment; also used to refer to the study of those interrelations. (B4)

**ecosystem\*** One or more biological community occupying a particular physical environment is known as an ecosystem. (B4, A7.1)

**effusive eruption\*** A volcanic eruption in which magma from a volcano flows over the ground as a continuous stream of lava. This style of eruption contrasts with that of a pyroclastic eruption. (B3)

**elasticity** The property of a solid material whereby any change in shape is reversed as soon as the deforming force is removed. (B8)

**electric charge\*** A fundamental property of matter. There are two types, positive and negative charge. Like charges repel each other with an electric force, and unlike charges attract each other. Objects with no charge, or with equal amounts of positive and negative charge, are electrically neutral. The SI unit of charge is the coulomb, with the symbol C. (B5)

**electric constant** See Coulomb constant.

**electric current\*** The flow of charged particles constitutes an electric current. Current  $I$  is the rate of flow of electric charge  $Q$ , so  $I = Q/t$ . In metals the current is due to a flow of electrons. The SI unit of current is the ampere, with the symbol A. (B5)

**electric force\*** ( $F_e$ ) The force produced on a charged object by another stationary electric charge or produced by a varying magnetic force. See also Coulomb's law. (B5, B11)

**electrical conductor** A material through which an electric current will flow. Metals are good electrical conductors, and the current through them is carried by electrons. (B5)

**electrical energy\*** Potential energy that an object has because it is electrically charged. The change in electrical energy  $\Delta E_e$  when electric charge  $Q$  moves through a voltage difference  $\Delta V$  is given by the equation  $\Delta E_e = Q\Delta V$ . (B5)

**electrical insulator** A material through which an electric current will not flow. Plastics, ceramics and glass are examples of electrical insulators. (B5)

**electrode\*** One of the two parts of the external circuit that make contact with the solution during electrolysis. (B6)

**electrolysis\*** The chemical decomposition of a liquid or a liquid solution that occurs during the conduction of electricity. (B6)

**electromagnetic interaction\*** One of the four fundamental interactions. In most situations it is adequately described by Maxwell's laws of electromagnetism. However, by incorporating the effects of quantum physics and Einstein's theory of special relativity, the modern theory of quantum electrodynamics provides a better description on very small size scales and in high-energy situations. It explains interactions between particles that possess electric charge in terms of the exchange of quanta called photons. It unifies all electric, magnetic and radiation phenomena into a single theory. Electromagnetic interactions are characterized by the dimensionless number referred to as the fine structure constant,  $\alpha_{em}$ . Electromagnetic interactions get stronger with increasing energy of interaction. Compare this behaviour with that of the strong interaction. (B11)

**electromagnetic radiation\*** A form of radiation that involves variations in electric and magnetic effects. Electromagnetic radiation is divided into subranges on the basis of the wavelength of the waves that comprise the radiation, and includes radio waves, microwaves, infrared radiation, light (visible radiation), ultraviolet (UV) radiation, X-rays and gamma-rays. (B2) The radiation given off by an accelerating electric charge in accord with Maxwell's laws of electromagnetism. Compare with gravitational radiation. (B11)

**electromagnetic spectrum** The entire range of electromagnetic radiation from radio waves, through microwaves, infrared radiation, light, ultraviolet (UV) radiation, and X-rays to gamma-rays. All electromagnetic radiation propagates as waves with the speed of light  $c = 3.00 \times 10^8 \text{ m s}^{-1}$ , but interacts with matter (i.e. is emitted or absorbed) as a stream of particles, called photons. (B7)

**electron\*** One of the component particles from which an atom is made. Electrons have a negative electric charge, and they surround the atom's positively charged nucleus. Electrons carry the electric current in metals. (B5) A fundamental particle (a lepton) with charge  $-e$ . Electrons ( $e^-$ ) are created in beta-minus decay and are ejected from metals in the photoelectric effect. See also electron charge. (B7)

**electron antineutrino\*** ( $\bar{\nu}_e$ ) A fundamental particle (an antilepton) with zero electric charge. It is produced in beta-minus decay along with an electron. (B7)

**electron capture\*** A type of radioactive decay in which an atomic nucleus with too many protons captures an electron. The effect is for one proton to turn into a neutron with the emission of an electron neutrino. The effect on the nucleus is the same as beta-plus decay. (B7, A5.1)

**electron carrier** Components of the inner mitochondrial membrane and the grana of chloroplasts that bind electrons and pass them to the next carrier in the electron transport chain. (B9)

**electron charge** ( $-e$ ) The charge on an electron is  $-1.602 \times 10^{-19} \text{ C}$ . See also electron and proton. (B11)

**electron cloud** See electron probability cloud.

**electron configuration\*** A shorthand notation to describe the quantum states occupied by the electrons in an atom. (B7) In this description of the electron



structure of an atom or ion, the symbols for the occupied sub-shells are written down in sequence, and the number of electrons in each one is specified by a superscript number. For example, the electron configuration of the oxygen atom is  $1s^2 2s^2 2p^4$ . (B8)

**electron neutrino\*** ( $\nu_e$ ) A fundamental particle (a lepton) with zero electric charge. It is produced in beta-plus decay along with a positron. (B7)

**electron probability cloud\*** A pictorial representation showing the relative probabilities of finding an electron in different regions in the vicinity of an atomic nucleus. (B7)

**electron scattering** The process by which a free electron and a photon interact. Usually the photon will initially have more energy than the electron, and the result of the scattering is that the electron gains energy, whilst the photon loses energy. (B11)

**electron structure** A general term for the arrangement of the electrons within an atom or ion. (B8)

**electron transport\*** The transfer of electrons along a series of carriers called the electron transport chain in the inner mitochondrial and inner chloroplast membranes. In the mitochondria this electron transfer brings about the oxidation of the reduced coenzyme NAD.2H as part of Stage 4 of glucose catabolism, whereas in the chloroplast the transfer of electrons produces reduced coenzyme NADP.2H as part of the light reactions of photosynthesis. (B9)

**electron transport chain\*** (ETC) The linear array of electron carriers in the inner mitochondrial membrane (and inner chloroplast membrane). The carriers are arranged in order of electron affinity. In the mitochondria, the carrier with the lowest electron affinity lies at one end and receives electrons from NAD.2H and passes them to its neighbour which has a slightly higher affinity. Electron transport continues in this stepwise way to the last carrier, cytochrome oxidase, which has the highest electron affinity; this passes the electrons to oxygen and water is thereby produced. (B9)

**electronegativity\*** The power of an atom to attract electrons to itself when forming chemical bonds with other atoms. (B8)

**electronvolt\*** (eV) A unit of energy corresponding to the energy converted when an electron moves from one terminal of a 1 V battery to the other. Numerically it is equal to  $1.602 \times 10^{-19}$  J. The energy of photons of light is conveniently expressed in units of electronvolts, but the energy of a fundamental particle is usually expressed in MeV ( $10^6$  eV) or GeV ( $10^9$  eV). (B7)

**electroweak interaction** The name given to the combined electromagnetic interaction and weak interaction that is in evidence at energies greater than about 1 000 GeV. (B11)

**electroweak unification\*** The name given to the process whereby the electromagnetic interaction and the weak interaction become unified at energies of around 1 000 GeV. Theories for this process predict that so-called Higgs bosons will be in evidence at reactions occurring at this energy. (B11)

**element** See chemical element.

**elliptical galaxy** A galaxy that has a regular shape, ranging from spherical, to tangerine-shaped, to rugby ball-shaped: it has no disc or spiral arms. (B3)

**embryo** A stage of development in some organisms between zygote and birth. (B4)

**emission line\*** A spectral line produced when atoms of a particular type emit photons with a particular energy. (B7)

**emission spectrum\*** The spectrum of light and other electromagnetic radiation emitted by an object. When a vapour of atoms is excited by, for example, the passage of an electric current, the emission spectrum contains emission lines of specific colours (each corresponding to a specific energy, wavelength or frequency) characteristic of the atoms. (B7)

**emitted radiation\*** The radiation that originates from energy within an object and is given out by the object. (B2)

**empirical formula\*** A formula that represents with chemical symbols the simplest ratio between the numbers of the different types of atom in a chemical compound. For example, carbon and hydrogen form a compound called ethane, in which the atomic ratio C : H is 1 : 3. The empirical formula is therefore  $\text{CH}_3$  even though it is also known that ethane is composed of molecules with the molecular formula  $\text{C}_2\text{H}_6$ . (B6)

**endemic\*** Found only in one place. The 'place' can be small or large but it must be a continuous area. For example, a species can be endemic to a continent (e.g. Antarctica), a particular geographic region (e.g. the Alps), a group of islands (e.g. the Galapagos Islands) or a single island (e.g. Genovesa island in the Galapagos). (B4, A9.1)

**endosymbiosis** An association between a host cell and a 'lodger' organism such as a bacterium, which is mutually beneficial. (*Endo-* means 'inside' and *symbiosis* means 'living together'.) (B9)

**endosymbiotic hypothesis\*** A proposal that provides a unifying concept to account for the evolutionary relationships of all cell types. It suggests that the earliest eukaryote cells had only a nucleus. Mitochondria and chloroplasts were originally free-living bacteria which moved into the eukaryote 'host' cells. Eventually the bacterial partners became completely integrated into and dependent on the host cells. (B9)

**endothermic reaction\*** A chemical reaction during which energy in the form of heat is transferred to the reacting chemicals, the system, from their surroundings. The enthalpy change  $\Delta H$  is positive for an endothermic reaction. Contrast exothermic reaction. (B8)

**energy\*** A physical property possessed by an object. It measures the capacity of the object to make changes to other objects. There is a variety of possible changes, and these include changes in motion. The SI unit of energy is the joule, with the symbol J. (B2) Energy has various forms, including kinetic energy, gravitational energy, internal energy, chemical energy and electrical energy, but the law of conservation of energy applies in all processes that involve conversions or transfers of energy. (B5)

**energy barrier\*** When reactant molecules encounter each other, they will only react to form product



molecules if they encounter each other with sufficient energy to overcome an energy barrier. (B8)

**energy levels\*** Specific values of energy that an atom (or other bound quantum system) is allowed to have. Transitions occur between two energy levels, in the process of which photons are emitted or absorbed. The energy levels of the hydrogen atom have values given by

$$E_n = \frac{-13.60 \text{ eV}}{n^2}$$
, where  $n = 1$  corresponds to the ground state. (B7)

**energy-level diagram\*** A pictorial representation of energy levels. Each energy level is represented by a horizontal line and the higher the line appears on the diagram, the higher is the energy of the level that it represents. (B7)

**energy-time uncertainty relation\*** A consequence of the Heisenberg uncertainty principle which states that an amount of energy  $\Delta E$  may be 'borrowed' for a time  $t$  provided that  $\Delta E \times t < h$  where  $h$  is the Planck constant. It allows electron-positron pairs to be created spontaneously inside atoms for a brief amount of time. (B11)

**enthalpy\*** For a given substance the enthalpy can be thought of as a kind of energy store that provides, or accepts, energy in the form of heat. This idea is reflected in the original derivation of the term — it comes from the Greek words for 'heat inside'. (B8)

**enthalpy change\*** A measure of the heat that is transferred for a process that occurs at both constant temperature and constant pressure. The symbol for enthalpy is  $H$  and that for enthalpy change is  $\Delta H$ . Enthalpy change is positive for an endothermic reaction and negative for an exothermic reaction. (B8)

**enthalpy of vaporization\*** The enthalpy change associated with the conversion of a liquid into a gas. It can be represented as  $\Delta H(\text{vaporization})$  or just  $\Delta H(\text{vap})$ . Also known as the latent heat of vaporization. (B8)

**enzyme** A protein that binds specific molecules and then transforms them into different substances. Enzymes are biological catalysts. (B8)

**enzyme-substrate complex\*** (ES) The one-to-one complex that is formed when the substrate binds to the active site of an enzyme by weak bonds. Once the complex is formed, catalysis occurs, the product is released and the enzyme is regenerated. (B9)

**epicentral angle** The angular measure of distance between a seismometer and an earthquake, given by the angle between the radius from the centre of the Earth to the epicentre and from the centre of the Earth to the seismometer. (B3)

**epicentre\*** The point on the Earth's surface directly above the focus of an earthquake. (B3)

**equation\*** A means of showing that two (mathematical) expressions are equal to each other. An equation such as  $24 + 42 = 66$  has two sides, which are separated by an equals sign ( $=$ ), and which are exactly equal to each other. (B1)

**equation of a straight line\*** The algebraic equation  $y = kx + c$  that relates pairs of values of  $x$  and  $y$  which, when plotted on a graph, lie along a straight line of gradient  $k$  and intercept with the vertical axis at  $c$ . (B7)

**equator** (cell) Position in the cell along which the chromosomes become aligned at metaphase of nuclear division, and where new cell membrane is produced, so dividing the cytoplasm between the two progeny cells. (B9, A8.4)

**equilibrium\*** See chemical equilibrium.

**equilibrium constant\*** A mathematical quantity, symbol  $K$ , derived from a balanced chemical equation. When the coefficients in the equation are all equal to 1, the equilibrium constant is found by multiplying together the concentrations of the products and dividing the result by the value obtained by multiplying together the concentrations of the reactants. When the system defined by the balanced equation is in chemical equilibrium, this quantity is constant at constant temperature. (B8)

**equilibrium yield\*** The amount of product present when a chemical reaction is in equilibrium. (B8)

**equivalent fraction\*** Any fraction can be expressed as a variety of equivalent fractions, each of which has an equal value. For example,  $\frac{1}{3}$  equals  $\frac{2}{6}$  (both the top and the bottom have been multiplied by 2), which equals  $\frac{6}{18}$  (both top and bottom have been multiplied by 3), so  $\frac{1}{3}$ ,  $\frac{2}{6}$ ,  $\frac{6}{18}$  are equivalent fractions. (B1)

**era\*** An interval of geological time, shorter than an eon and longer than a period. The Phanerozoic Eon is divided into the Palaeozoic, Mesozoic and Cenozoic Eras. (B10)

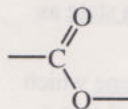
**erosion\*** The wearing away of the Earth's surface by the mechanical removal of rock and mineral fragments due to the action of flowing water, ice or wind, and the abrasive action of moving debris. Contrast weathering. (B3, B10)

**erratic\*** A boulder that was transported for some distance from its point of origin by moving ice, and which was left behind when the ice melted. (B2)

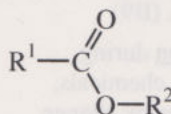
**error bar** A means of representing the uncertainty in a measured quantity on a graph. If the value of the quantity is  $Y$  and the uncertainty is  $\pm y$ , then one end of the error bar is plotted at  $Y + y$ , and the other end at  $Y - y$ , and a line is drawn between the two points. Thus the error bar spans the range of values that are consistent with the measured quantity. (B7, A10.1)

**ES\*** See enzyme-substrate complex.

**ester** A compound with molecules containing an ester group,



Esters have the general formula



(B8)

**estimate** An approximate value of a quantity, which is not based on precise measurements or exact calculations. For example, you might estimate the height of a person to be about 1.7 m, or you might estimate the area of a

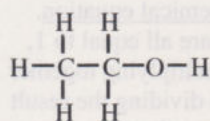


room measuring  $4.23 \text{ m} \times 2.92 \text{ m}$  to be  $(4 \times 3) \text{ m}^2$ , or  $12 \text{ m}^2$ . (B1)

**ETC\*** See electron transport chain.

**ethanol** An alcohol with the molecular formula  $\text{C}_2\text{H}_5\text{OH}$ , the abbreviated structural formula

$\text{CH}_3\text{—CH}_2\text{—OH}$  and the structural formula



(B8)

**Eukarya\*** The domain that includes all except prokaryote organisms (which belong to either Archaea or Bacteria). (B4)

**eukaryote\*** (adjective: eukaryotic) An organism in which each cell typically contains a nucleus in which genetic material is found. Eukaryotic organisms are members of the domain Eukarya. Compare with prokaryote. (B4)

**evaporation\*** The process whereby a substance changes from the liquid state to the gaseous state, e.g. liquid water evaporates to form water vapour. The conversion of a liquid into a gas is also often called vaporization. (B1) The evaporation of water from an aqueous solution of a solid usually leads to the eventual crystallization of the solid. (B6)

**evaporite\*** A sedimentary rock formed in hot climates by evaporation of salty water to precipitate salts such as the minerals halite (common salt), gypsum and anhydrite. Evaporites may form in enclosed basins, and along arid shorelines. (B10)

**evolution\*** The process of change; used in biology to refer to the fact that the organisms that inhabit the Earth today are different from those that existed in the past. This change has been brought about mainly by natural selection. (B4)

**evolutionary radiation\*** An episode of rapid and sustained increase in biodiversity, often involving the origin of many new groups above the species level, such as orders and families. An example is the radiation of mammals in the early Cenozoic. (B10)

**excited state\*** Any quantum state that is not the ground state. (B7)

**exclusion principle\*** A rule of quantum physics, described by Wolfgang Pauli, which forbids an electron in one atom from occupying the same quantum state as any other electron. (B7)

**exons\*** The coding sequences within a split gene which together constitute the mRNA and are translated into a polypeptide. The exons in a gene are interspersed with non-protein coding regions termed introns. (B9)

**exothermic reaction\*** A chemical reaction during which heat is transferred from the reacting chemicals, the system, to their surroundings. The enthalpy change  $\Delta H$  is negative for an exothermic reaction. Contrast endothermic reaction. (B8)

**expansion** (of the Universe) This refers to the fact that, on large scales, the separations of objects in the Universe are increasing because space itself is expanding. (B11)

**explosive eruption** See pyroclastic eruption.

**exponential\*** An exponential change is one in which the value of a quantity decreases or increases by the same factor in equal intervals. Thus the shape of the graph obtained by plotting the number of radioactive decays from a sample against time is described as an exponential decay, or a falling exponential since the graph falls by a constant factor of two for every half-life that elapses. (B7, A5.1)

**extinction** The disappearance of an entire species from the Earth. Local extinctions are also recognized, in which a species disappears from a specified part of the Earth. See also mass extinction. (B4)

**extracellular matrix** A network of macromolecules (proteins and polysaccharides) secreted by cells and permeated by fluid, which surrounds the cells in most animal tissues. (B9)

**extrusive\*** The term applied to igneous rocks, including lavas and pyroclasts, that are erupted onto the Earth's surface during volcanic activity. Synonymous with volcanic. Extrusive rocks, such as basalt, are characterized by fine grain size due to rapid cooling. Contrast with intrusive. (B10)

**F<sub>1</sub>** See first filial generation.

**F<sub>2</sub>** See second filial generation.

**faeces\*** Matter that is consumed by an animal but which passes through its body without becoming assimilated material. (B4, A7.1)

**family** The level of taxonomic classification between order and genus. For example, the family Felidae (cats) is part of the order Carnivora and comprises four genera including Felis (in which the domestic cat is classified). (B4)

**fatty acid\*** A long-chain carboxylic acid produced from fats by hydrolysis. (B9)

**fault\*** A break or fracture in rock along which movement has occurred. (B3) Faults are a form of brittle deformation, and may be caused by compression or by tension. (B10)

**favourable conditions** Environmental conditions under which an organism can show the three attributes of life. Favourable conditions can vary in quality from ideal (or optimal) to those under which life is only just possible for the organism. (B4)

**feedback\*** This occurs when a change in one quantity causes changes to other quantities that eventually lead to a further change in the original quantity. See also negative feedback, positive feedback. (B2)

**feldspar\*** A framework silicate mineral found in many igneous, sedimentary and metamorphic rocks. Alkali feldspar contains sodium and potassium. Plagioclase feldspar contains sodium and calcium. (B10, A4.2)

**felsic\*** Term used to describe the pale-coloured minerals of igneous rocks, especially the feldspars and quartz. Pale igneous rocks dominated by felsic minerals are known as felsic rocks. (B10)

**fermentation** The process of anaerobic respiration in yeast, in which pyruvate is converted into alcohol and carbon dioxide and NAD is regenerated. (B9)

**ferromagnesian mineral** A mineral containing appreciable amounts of iron and magnesium. Mainly



dark-coloured minerals, including olivine, pyroxene and amphibole; *see also* mafic. (B10, A4.1)

**fertilization** A male gamete is said to fertilize a female gamete when they fuse to give rise to a zygote; also used more loosely to describe the transfer of gametes from one organism to another prior to fusion of the gametes. (B4)

**Feynman diagram\*** A pictorial way of representing reactions involving quarks, leptons and quanta such as photons, gluons, W bosons and Z bosons. Mathematical expressions can be associated with each line or intersection in such a diagram to enable probabilities for different reactions to be calculated. (B11)

**fibrous protein\*** Protein that has an elongated, roughly linear shape, in which long fibres may be wound round one another like a rope. They form structural materials providing support, e.g. collagen, muscle proteins, keratin. (B9)

**filter feeder** An organism that uses some kind of filtering mechanism to trap small particles of food suspended in the water in which it feeds. (B4, A9.1)

**filtration\*** A process in which a solid and a liquid are separated by using a porous partition of paper or sintered glass. The liquid passes through the pores in the partition, but the particles of the solid do not. (B6)

**fine structure constant\*** ( $\alpha_{em}$ ) A dimensionless number that characterizes the strength of the electromagnetic interaction. It has a value given by  $\alpha_{em} = \frac{1}{137}$  at low energies. (B11)

**first filial generation\*** ( $F_1$ ) The first generation of offspring produced when two parental varieties are crossed. (B9)

**fissile** The tendency of a rock (e.g. shale, slate) to split easily into thin layers. It may be due either to the alignment of platy minerals (clay and/or mica) or to a series of thin, alternating layers of different sediment (mud and silt). (B10)

**fission\*** *See* nuclear fission.

**fitness\*** The relative ability of an organism to survive and leave offspring that themselves survive and leave offspring. Sometimes only one or more component of fitness can be measured. (B4)

**flat Universe\*** A model of the Universe in which the density of matter is exactly equal to the critical density. Such a Universe will continue expanding, but at an ever-decreasing rate. It will only reach a zero rate of expansion at an infinite time in the future. A flat Universe is infinite in size at all times. It is most probable that we live in a flat Universe. (B11)

**flow diagram** A means of summarizing a number of points, ideas or processes, each of which is linked to others by arrows that show the logical sequence. (B1)

**flux** The rate of flow of some entity from one location to another, such as solar radiation from the Sun to the Earth, or water from one reservoir to another. *See also* brightness. (B2)

**focus\*** (of an earthquake: plural foci) The location (point of origin) of an earthquake. This is usually below the Earth's surface. (B3)

**fold\*** The bending or crumpling of rock layers which may occur on a wide variety of scales. Folds are a form of plastic deformation, and are most often caused by compression. (B10)

**foliation\*** The layering in metamorphic rocks formed by banding of minerals or the parallel alignment of platy minerals. A characteristic texture of regionally metamorphosed rocks that is caused by pressure during deformation (*see* regional metamorphism). (B10)

**food chain\*** A simple sequence, beginning with an autotroph, in which a species at one trophic level is consumed by another species at a higher trophic level, which may in turn be consumed at a still higher level. (B4, A7.1)

**food web\*** A complex sequence, beginning with an autotroph, in which a species at one trophic level is consumed by several species at other trophic levels, which may in turn be consumed by several other species. (B4, A7.1)

**force\*** A disturbance that tends to accelerate an object. Forces can negate the effects of other forces, so acceleration will ensue only if an unbalanced force acts on a body. In SI units, the unit of force is the newton (N). (B3) When a force causes an object to move, work is done on that object. (B5)

**foreshock** A smaller earthquake (usually one of a series) preceding a large earthquake. (B3)

**formula unit\*** The chemical formula for a substance that must be specified if the meaning of the phrase 'one mole of the substance' is to be precise and complete. (B6)

**fossil\*** Any evidence of ancient life, usually preserved in sedimentary rocks. (B2) *See also* body fossil, trace fossil. (B10)

**fossil fuel\*** A general term for combustible geological deposits of organic carbon. It includes coal, oil, natural gas, oil shales, and tar sands. (B2)

**founder effect\*** The phenomenon whereby the frequency of a particular character in a population is largely determined by the frequency of that character in the small original (or founding) population rather than by the subsequent operation of natural selection. (B4)

**four fundamental interactions\*** The electromagnetic interaction, the strong interaction, the weak interaction and the gravitational interaction which are believed to be at the heart of all processes that occur in the Universe. (B11)

**fraction\*** A quantity that is part of a whole. For example  $\frac{3}{8}$ , which can also be written as  $3/8$ , represents three of the eight equal parts into which an object can notionally be divided. The term also includes 'top heavy' fractions, such as  $3/2$  and  $8/3$ , which are greater than one. (B1)

**fractional crystallization\*** The process by which early-formed crystals, usually of mafic minerals, become separated from the magma in which they crystallized to leave a magma with different composition. An important cause of magmatic diversity. Compare partial melting. (B10)



**fractions** (of crude oil) Crude oil can be separated by distillation into fractions, each of which has a distinctive range of boiling temperatures. (B8)

**free-bound emission** A process in which a free electron (i.e. one not bound to a nucleus in an atom or ion) becomes bound to a nucleus. In the process the electron loses energy and emits a photon of electromagnetic radiation. Also referred to as recombination. (B11)

**free-free absorption** A process in which a free electron (i.e. one not bound to a nucleus in an atom or ion) absorbs a photon of electromagnetic radiation and so gains energy. The photon disappears in the process and the electron remains free after the event. (B11)

**free-free emission** A process in which a free electron (i.e. one not bound to a nucleus in an atom or ion) emits a photon of electromagnetic radiation and so loses energy, but remains free after the event. The usual way in which this happens is when an electron accelerates when passing close to a positively charged particle such as a nucleus. (B11)

**freezing\*** The transformation of a liquid into a solid. It involves a transition from a state in which the particles that make up the substance swap positions to one in which the particles occupy specific positions. (B2)

**freezing temperature\*** The temperature at which a liquid freezes, i.e. turns to solid on cooling. This temperature depends on various factors, and the *normal* freezing temperature is the temperature at which the liquid freezes at sea-level under normal atmospheric conditions. (These conditions are defined in Block 2.) On the Celsius scale the normal freezing temperature of water is 0 °C. (B1)

**frequency\*** (of a wave) ( $f$ ) The number of complete cycles of a wave that pass a certain fixed point in a unit of time. Conventionally measured in the SI unit of hertz, Hz (or equivalently  $\text{s}^{-1}$ ). It is equal to one over the period of a wave,  $f = \frac{1}{T}$ , and related to the wavelength  $\lambda$  and speed  $v$  of a wave by  $v = f\lambda$ . (B7)

**friction** A force that one object exerts on another, and which acts to reduce or prevent their relative motion. When friction acts on a moving object, kinetic energy is converted into internal energy and the temperature of the object increases. (B5)

**functional group\*** In many reactions of organic compounds, it is observed that only certain groups of atoms are directly involved. It is the nature of these groups of atoms that primarily determines the type of reaction that takes place; the constitution of the hydrocarbon portion of the molecule has little influence. Such groups of atoms are called functional groups, and common examples are the alcohol group, the amine group, and the carboxylic acid group. (B8)

**functional group approach\*** An approach to the study of chemical reactions of organic compounds that involves the hypothetical separation of an organic molecule into an unreactive hydrocarbon portion and a reactive functional group. (B8)

**fundamental particle\*** Any particle that is not made up of other particles. Leptons and quarks are fundamental particles, as are their antiparticles. (B7)

**Fungi\*** The formal name for the fungi kingdom (singular: fungus), one of four kingdoms within the domain Eukarya. A fungus is a heterotroph and a typical fungus is a multicellular organism. (B4)

**gabbro\*** A coarse-grained, intrusive igneous rock, with the same chemical composition as basalt, formed by the slow cooling of basaltic magma at depth within the Earth's crust. Gabbro and its extrusive equivalent, basalt, are the principal components of the oceanic crust. (B3)

**Galactic centre** The centre of the Galaxy. (B3)

**Galactic disc** A thin disc in the Galaxy in which stars and interstellar matter are concentrated. The Sun is one of many stars in the disc. (B3)

**Galactic halo** A roughly spherical, poorly-defined volume enclosing the Galactic disc, and extending well beyond it. There are fewer stars and less interstellar matter in the halo than in the disc, though most of the dark matter is in the halo. (B3)

**Galaxy\*** The assemblage of about  $10^{11}$  stars, interstellar matter, and dark matter, in which the Sun is located. (B3)

**galaxy\*** (general) A collection of a large number of stars and interstellar matter, and often some dark matter. (B3)

**gall** Any unusual growth of a plant which is caused by a parasite. (B4, A7.1)

**gamete\*** A haploid cell capable of fusing with another gamete in sexual reproduction to give rise to a diploid zygote. See fertilization. (B4)

**gamma-decay\*** ( $\gamma$ -decay) A radioactive decay process in which an atomic nucleus makes a transition from an excited state to a lower energy state and loses energy by emitting a gamma-ray. The mass number and atomic number of the nucleus are unchanged. (B7)

**gamma-ray** ( $\gamma$ -ray) A type of electromagnetic radiation of short wavelength which is commonly emitted during radioactive decay. It is not deflected by a magnetic field, and this distinguishes it from alpha-particles and beta-particles. (B6)

**gas\*** See gaseous state.

**gaseous state\*** One of the three states in which substances can exist; the other two are solid and liquid. An example of a gas is water vapour — the gaseous state of water. (B1) In the gaseous state the particles that make up a substance are far apart so there is little attraction between them. They move in a random manner, occasionally colliding with each other. (B2)

**Gay-Lussac's law\*** If the volumes in which gases react are measured at the same temperature and pressure, they turn out to be in a simple ratio to one another, and to the volume of the product if it is also gaseous. (B6)

**gene\*** The fundamental unit of inheritance; the physical unit recognized through its variant alleles. Also a unit of function that transmits information from one generation to the next. (B9)

**gene flow\*** Exchange of genes and alleles between populations. (B9)

**gene mutation\*** One type of mutation. An heritable genetic change that results from changes in the DNA of



a gene, such as the deletion or addition of bases or the change of a base(s) to a different base. (B9)

**gene pool\*** The sum total of all alleles present in a population at a particular time and thus includes all the genetic variation between individuals in a population. (B9)

**genera\*** Plural of genus. (B4)

**general relativity\*** The description of the gravitational interaction given by Einstein. It is appropriate in situations where the masses involved are very large, or when massive objects undergo large accelerations. It predicts that massive objects undergoing large accelerations will be a source of gravitational radiation. (B11)

**generation time\*** The time it takes a particular type of organism to go once around its life cycle. (B4)

**genetic bottleneck\*** The reduction of the genetic variability in a population resulting from a period of small population size. Since the surviving individuals carry only a small proportion of the original gene pool of the population, if population size subsequently increases again, there is much less genetic variation present in the population than there was previously. (B9)

**genetic code\*** The set of rules that specify the correspondence between the nucleotide triplets in DNA or RNA and the amino acids in a polypeptide (protein). There are 64 triplet codons; not all of these code for particular amino acids since three of them are stop codons. The genetic code is universal. (B9)

**genetic drift\*** Variation in the frequency of a particular character in a population between one generation and the next due to chance rather than to the operation of natural selection; the effects of genetic drift are most evident in small populations. (B4)

**genetic map\*** A chromosome map of the order of genes (based on recombination frequencies). (B9, A8.4)

**genetic material** The genetic material of most organisms is DNA. An organism's genetic material is inherited from its parent(s) and all or just half of it is copied to its own offspring (in asexual reproduction and sexual reproduction respectively). During cell division, a complete set of the DNA of the parent cell ends up in each of the progeny cells. The precise nature of an organism's DNA influences many aspects of its life. (B4)

**genome\*** The total genetic material within a cell or organism. Genomes usually consist of DNA, but the genomes of some viruses contain only RNA. (B9)

**genotype\*** The specific composition of alleles of a single gene, or the entire complement of genes of an organism. (B9)

**genus\*** (plural: genera) The level of taxonomic classification between family and species. For instance, the genus *Felis* is part of the family Felidae (cats) and comprises 31 species including *F. catus* (domestic cat). The first part of an organism's scientific label is the genus to which it belongs. (B4)

**geochemical cycle\*** That part of a biogeochemical cycle that involves the slow cycling of material from one geological reservoir to another. (B2)

**geological record\*** A record of ancient conditions and life preserved in rocks. The rocks on the Earth have been

formed by many different processes, such as the eruption of lava from volcanoes and the deposition of sediment from rivers and glaciers. The resultant rocks are specific to the processes involved. Because different animals and plants require particular climatic or environmental conditions to thrive, the types of fossil that a rock contains indicate the type of conditions prevailing at the time when they lived. (B2)

**geomagnetic polarity time-scale\*** The Earth's magnetism has changed polarity at irregular intervals of several million years or less. The ages of each polarity reversal form a sequence which defines the geomagnetic polarity time-scale. (B3)

**geothermal gradient\*** The rate at which temperature increases with depth in the Earth. It varies from one tectonic setting to another, but is commonly about  $25\text{ }^{\circ}\text{C km}^{-1}$ . (B10)

**giant planets\*** The four large planets in the Solar System: Jupiter, Saturn, Uranus, Neptune. (B3)

**giga\*** A prefix to a unit, which means 'one billion' or  $10^9$ ; for example, a gigawatt is one billion watts,  $1\text{ GW} = 10^9\text{ W}$ . (B2)

**glacial periods\*** Periods of time within an ice age during which glaciers and ice-caps cover substantial areas of the Earth. The last glacial period ended about 10 000 years ago. Compare with interglacial periods. (B2)

**glaciers\*** Large, slowly flowing masses of ice. (B2)

**global mean surface temperature (GMST)\*** The mean surface temperature averaged over the whole surface of the Earth, both land and sea. The GMST is calculated from measurements taken over one or more years. (B2)

**Global Positioning System (GPS)** A navigation system that uses radio signals from navigation satellites. (B3)

**globular cluster** A globe-like cluster of up to about a million stars. (B3)

**globular protein\*** Protein that is usually coiled into broadly spherical shapes. The precise globular structure arises directly from the primary structure of the polypeptide as a consequence of the formation of weak bonds between specific functional groups (R groups) of amino acids. Globular proteins have more specialized roles than fibrous proteins, acting as cell receptors or enzymes, for example. (B9)

**glucose** A monosaccharide with the molecular formula  $\text{C}_6\text{H}_{12}\text{O}_6$ . Glucose is a major metabolic fuel and is also the constituent monomer of several important polysaccharides, e.g. glycogen and cellulose. (B9)

**gluon\*** The quantum of energy associated with the strong interaction. It plays a role in quantum chromodynamics analogous to that of photons in quantum electrodynamics. Unlike photons, gluons themselves experience the strong interaction (photons do not experience the electromagnetic interaction). This is because gluons possess colour charge (photons do not possess conventional electric charge). Consequently gluons have a very short range and are never observed in isolation. (B11)

**glycerol** An alcohol which condenses with three fatty acid molecules to give a triacylglycerol. (B9)



**glycogen** An energy storage polysaccharide found in animals, particularly liver and muscle. Chemically, it is composed of branched chains of glucose. (B9)

**glycolysis\*** The sequence of reactions that forms Stage 1 of glucose catabolism. In this metabolic pathway glucose is converted into two molecules of pyruvate in the cytosol, with the net production of two NAD<sub>2</sub>H and two ATP molecules (by substrate-level phosphorylation). The catabolism of glycerol and some amino acids feeds into the pathway of glycolysis. (B9)

**glycosidic linkage\*** The covalent bond joining adjacent sugars in a polysaccharide. It is formed by a condensation reaction. (B9)

**GMST** See global mean surface temperature.

**gneiss\*** A coarse-grained metamorphic rock, with a foliation due to alternating bands of light and dark minerals. The pale minerals are usually quartz and feldspar, the dark ones mostly ferromagnesian minerals. Gneiss is formed at high grades of regional metamorphism. (B10)

**GPP** See gross primary productivity.

**graded bedding\*** A progressive change in grain size of sediment from the base to the top of a bed. Beds in which grains get finer upwards are commonly developed during deposition from a waning current, and can be used to indicate the order of deposition in strata overturned by tectonic activity. (B10)

**gradient\*** (of a graph) The slope of a line on a graph, given by the change in vertical position (the rise) between two points divided by the corresponding change in horizontal position (the run). If the coordinates of two points on a straight line are  $(x_1, y_1)$  and  $(x_2, y_2)$  then the gradient of the graph is:

$$\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{rise}}{\text{run}}. \quad (\text{B3})$$

**grana\*** Stacks of folds of the inner membrane of the chloroplast. (B9)

**grand unification\*** The name given to the process whereby the electromagnetic interaction, the weak interaction and the strong interaction become unified at energies of around  $10^{15}$  GeV. Any theory for this process, known as a Grand Unified Theory or GUT, predicts that so-called X bosons will be in evidence at reactions occurring at this energy. (B11)

**Grand Unified Theory (GUT)** A theory expressing the grand unification of the electromagnetic interaction, the weak interaction and the strong interaction. (B11)

**granite\*** A coarse-grained intrusive igneous rock composed largely of interlocking crystals of three types of mineral: quartz, feldspar and mica. (B3) It often occurs as large plutons. (B10)

**graph\*** A means of illustrating the relationship between two variable quantities (such as mass and time) by plotting the value of one measured quantity using a scale along a horizontal axis and the value of the other using a scale along a vertical axis. (B1)

**gravitational constant (G)** The constant of proportionality in Newton's law of gravity; it has a value of  $6.672 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$ . (B11)

**gravitational energy\*** Work has to be done against the gravitational force to raise an object to a greater height, and

the energy transferred is stored as gravitational energy. This energy is released and can do work when the object falls. If an object with mass  $m$  is raised through a height of  $\Delta h$  in a region where the acceleration due to gravity is  $g$ , then the change in gravitational energy is  $\Delta E_g = mg\Delta h$ . Gravitational energy is a form of potential energy. It is only changes of gravitational energy that are important in energy transfers and conversions, which is why the  $\Delta$  (delta) notation is used. (B5)

**gravitational force ( $F_g$ )** The force on an object due to gravity, often called the weight of the object. The gravitational force  $F_g$  on an object is proportional to its mass  $m$ , and near the Earth's surface  $F_g = mg$ , where  $g$  is the acceleration due to gravity. See also Newton's law of gravity. (B5, B11)

**gravitational interaction\*** One of the four fundamental interactions. In most situations, the description of gravity provided by Newton's law of gravity is appropriate. However, when the masses involved are very large, or when massive objects undergo large accelerations, Einstein's theory of general relativity provides a better description. In the early Universe, when very small distance scales and enormous energy scales applied, a theory of quantum gravity is needed to provide a more appropriate description. (B11)

**gravitational radiation\*** The radiation given off by accelerating massive objects in accord with Einstein's theory of general relativity. Compare with electromagnetic radiation. (B11)

**graviton\*** The quantum of energy that is associated with the gravitational interaction. There is currently no experimental evidence for gravitons, but they are predicted to exist by any theory of quantum gravity. Gravitons themselves have no mass but would experience the gravitational interaction. Compare this behaviour with photons and gluons, which also have no mass: photons do not experience the electromagnetic interaction, but gluons do experience the strong interaction. (B11)

**gravity\*** A universal force that attracts any object (with mass) to any other object (with mass). (B3) In colloquial speech, the term is used to describe the attraction of objects on or near the Earth's surface towards the centre of the Earth. See also Newton's law of gravity. (B5)

**great circle\*** (on the Earth) A circle that passes through both the pole and the antipole of an axis through the centre of the Earth. A great circle has the same diameter as the Earth. Lines of longitude and the Equator are great circles, and the circle passing through both poles of a plate axis of rotation is also a great circle. (B3, A13.3)

**greenhouse effect\*** The rise in the surface temperature of a planet as a result of the radiation emitted by the planet's atmosphere. (B2)

**greenhouse gas\*** An atmospheric gas that contributes significantly to a planet's greenhouse effect by strongly absorbing longwave infrared radiation emitted by the planet's surface. Examples are carbon dioxide and water. (B2)

**gross primary productivity (GPP)\*** The amount of solar energy trapped by photosynthesis over a specified time and in a specified area or volume or in a specified



food chain, food web or ecosystem. Compare with net primary productivity (NPP). (B4, A7.1)

**ground state\*** The quantum state that corresponds to the lowest of the energy levels of an atom, or other quantum system. (B7) The arrangement of the electrons within an atom or ion that has the lowest energy. The electron configuration of the ground state can usually be found by progressively allocating electrons to sub-shells that have been arranged in order of increasing energy. (B8)

**groundmass** The finer-grained part of an igneous rock with porphyritic texture. (B10)

**group\*** (Periodic Table) A set of chemical elements, commonly placed in a vertical column in the Periodic Table because of similarities in chemical properties. (B6)

**growth\*** Increase in size of an organism or cell; one of the three attributes of life. (B4)

**growth I\*** A phase of the cell cycle in which the cell increases in size before replication of its DNA. (B4)

**growth II\*** A phase of the cell cycle in which the cell increases in size following replication of its DNA. (B4)

**Haber-Bosch process** The industrial process by which nitrogen gas is combined with hydrogen gas to give ammonia. The reaction is carried out at high temperature and pressure in the presence of a catalyst. (B8)

**habitat\*** The physical and biological environment in which an organism lives. (B4, A7.1)

**hadron\*** A subatomic particle composed of quarks and/or antiquarks. A baryon is a hadron consisting of three quarks; an antibaryon is a hadron consisting of three antiquarks; a meson is a hadron consisting of a quark and an antiquark. (B7)

**half-life\*** The time taken for half of the atomic nuclei in a radioactive sample to decay. See radioactive decay. (B7, A5.1)

**haloalkane** A compound with molecules containing only atoms of carbon, hydrogen and one or more of the halogens (fluorine, chlorine, bromine and/or iodine). (B8)

**halogens\*** The chemical elements fluorine, chlorine, bromine, iodine and astatine, which are placed in Group VII of the Periodic Table. The family name is derived from the Greek words *hals* (sea-salt) and *gennao* (I produce), because three of the elements (chlorine, bromine and iodine) can be prepared from sea-salt. (B6)

**haploid\*** A haploid cell is one in which each autosome does not have a similar-looking partner. Compare with diploid. (B4)

**heat** Energy that is transferred from a hotter region to a cooler region because of the temperature difference. At a microscopic level, transferring heat to a substance either increases the speeds of the atoms or molecules (observed on the large scale as a rise in temperature), or changes the state of the substance. (B2) In both cases, the internal energy of the substance or object increases. Heat is usually represented by the symbol *q*, and its SI unit is the joule, J. (B5)

**helioseismology\*** The study of oscillations on the surface of the Sun by which the interior structure,

density and composition of the Sun may be determined. (B11)

**herbivore\*** An organism that obtains its carbon-based materials by consuming living plant (or fungal) material, i.e. a type of heterotroph. Compare with carnivore, decomposer, detritivore. (B4)

**hertz\*** The SI unit of frequency, symbol Hz, equivalent to  $s^{-1}$ . (B7)

**heterotroph\*** An organism that cannot manufacture its own carbon-based materials starting from carbon dioxide and therefore feeds on other organisms. A heterotroph is also known as a consumer. Compare with autotroph and producer. (B4)

**heterozygote\*** An individual having a heterozygous gene or genes. (B9)

**heterozygous\*** Term describing a gene that has different alleles in the homologous chromosomes of a diploid set, usually one dominant and one recessive (e.g. *Gg*), but not always (e.g. the *A B* genotype of the ABO blood group system). (B9)

**heterozygous advantage\*** A situation in which individuals that are heterozygous at a particular genetic locus have an advantage under natural selection (i.e. have greater fitness) over either type of homozygote for that locus. (B9)

**hierarchical gravitational clustering** The process by which galaxies are believed to have formed in the early Universe. It is a 'bottom-up' process in which small fragments cluster together into larger and larger structures. (B11, A11.1)

**Higgs boson\*** A particle proposed to exist by current theories of electroweak unification. The Higgs boson will have a mass of around  $1\,000\text{ GeV}/c^2$ . (B11)

**higher-order structure\*** The three-dimensional folding pattern of a biopolymer, such as proteins. The shape of each biopolymer is unique and arises as a consequence of a particular arrangement of weak bonds, e.g. between amino acid R groups. Thus the primary structure of a biopolymer determines its higher-order structure. (B9)

**histogram** A graphical representation in which the horizontal axis is divided into a set of intervals (usually equal). On each of these intervals a rectangle is constructed with a width equal to the interval, and a height that represents the value of the quantity on the vertical axis that applies at the particular interval. For example, the intervals could be the months in the year, and the vertical axis could be the mean monthly rainfall. Note that there is no gap between the rectangles. (B2)

**homologous\*** Term describing chromosomes that are identical in shape, size and function. Each chromosome in a diploid organism (except sex chromosomes) has an homologous partner; one of the pair is inherited from the male parent and the other from the female. (B9)

**homozygote\*** An individual having an homozygous gene or genes. (B9)

**homozygous\*** Term describing a gene that has the same alleles in the homologous chromosomes of a diploid set (e.g. *AA* and *aa*). (B9)

**horizon distance\*** The maximum distance that light can have travelled since the Big Bang. In the non-



inflationary model for the expansion of the Universe, the horizon distance is equal to  $3ct$  and is roughly the same as the radius of the currently observable Universe. In the inflationary model for the expansion of the Universe, the horizon distance is much larger, thanks to the vast increase in scale accumulated during inflation. (B11)

**horizontal axis** See axis.

**hormone** Chemical messenger molecule secreted from specialized tissues into the bloodstream, in which it is transported to its site(s) of action. (B9)

**hot big bang** The name given to the scientific theory which describes the origin and early evolution of the Universe. Consequences of the hot big bang include the fact that space is expanding, that the temperature of the Universe is falling and that elements such as helium, lithium and deuterium have certain abundances in the Universe. See also Big Bang. (B11)

**hot spot\*** A volcanic area above a shallow region of anomalously hot mantle. (B3)

**Hubble constant\*** ( $H_0$ ) The constant of proportionality in the Hubble relationship which relates the speed of recession of distant galaxies to their distance away from us. The current best estimate of the Hubble constant is about  $60 \text{ km s}^{-1} \text{ Mpc}^{-1}$ . The Hubble constant was larger in the distant past than it is today. (B11)

**Hubble relationship\*** This expresses the fact that the further away a galaxy is from us, the faster it is receding. In symbols,  $v = H_0 r$  where  $H_0$  is the current value of the Hubble constant. (B11)

**hybridization** Cross-fertilization between two different species or varieties. (B9)

**hydrocarbon\*** A compound composed only of the elements carbon and hydrogen. (B6) Alkanes and alkenes are hydrocarbons. (B8)

**hydrocracking\*** The breaking down of high molecular mass hydrocarbon compounds, with the simultaneous addition of hydrogen, to produce saturated, low molecular mass, hydrocarbon compounds. (B8)

**hydrogen bond\*** A particularly important type of intermolecular attraction, weaker than the covalent bonds within molecules but stronger than London interactions. Hydrogen bonds usually occur between hydrogen atoms that are attached to oxygen or nitrogen atoms in one molecule, and oxygen or nitrogen atoms in an adjacent molecule. (B8)

**hydrogen-like ion\*** Any ion containing a single bound electron. Examples are  $\text{He}^+$ ,  $\text{Li}^{2+}$  and  $\text{Be}^{3+}$ . (B7)

**hydrolysis\*** Literally, breaking down (lysis) by water. A reaction in which a molecule (often an ester or an amide) is broken down into two or more smaller molecules through the reaction with one or more water molecules. An example is the hydrolysis of ethyl acetate by water to give ethanol and acetic acid. (B8)

**hydrophilic\*** Term describing a molecule or functional group that forms hydrogen bonds with water molecules and thus readily dissolves in water. Literally means 'water-loving'. (B9)

**hydrophobic\*** Term describing a molecule or functional group that is unable to interact with charges on water molecules and therefore does not dissolve in

water. Literally means 'water-fearing'. See also hydrophobic interaction. (B9)

**hydrophobic interaction** The process by which long hydrocarbon chains or benzene rings (see aromatic compounds), which are part of a larger molecule, tend to aggregate together when in an aqueous environment, thus minimizing their interaction with water molecules. (B8)

**hydrosphere\*** The water in, or on the surface of, the Earth (including the oceans, rivers, lakes, ice) together with water in the atmosphere. (B3)

**hydrothermal fluid\*** Hot metal-rich water discharged in volcanically active regions. At a mid-ocean ridge, the discharge of hydrothermal fluids can result in a black smoker. (B3, A12.1)

**hydroxyl** A chemical group consisting of a hydrogen atom and an oxygen atom (i.e. OH), as in an alcohol. Also known as an alcohol group. (B9)

**hypothesis\*** A tentative explanation, based on the available evidence, which accounts for observations or facts. It may be tested by making further observations, and may be modified in the light of new evidence or observations. (B1)

**hypsometric plot** A histogram showing the relative proportions of the Earth's surface area at different altitudes and depths. (B3)

**ice age\*** A period of time during which large parts of the Earth are repeatedly covered by glaciers and ice-caps. An ice age consists of alternating glacial periods and interglacial periods. (B2)

**icy materials\*** A term used in Solar System studies for materials that comprise water and other substances that look icy when frozen, though they can be liquid in the interiors of planets. (B3)

**igneous rock\*** Any rock formed by the solidification of magma, either underground (an intrusive igneous rock) or after eruption on the Earth's surface (an extrusive igneous rock). Igneous rocks are characterized by an interlocking crystalline texture, and can be coarse-grained if intruded and cooled slowly, or fine-grained if they erupt and are cooled quickly. (B3)

**incomplete dominance** The situation in which a heterozygote shows a phenotype intermediate between the phenotypes of the corresponding homozygotes. (B9)

**independent assortment\*** Different segregating genes behave independently at meiosis and this can lead to the recombination of genes and alleles. This is brought about because an homologous pair of chromosomes becomes aligned along the equator of the cell during metaphase independently of any other homologous pair. (B9)

**independent variable** A quantity, the value of which is chosen by the investigator. On a graph, the independent variable is plotted on the x axis. For example, if an investigator selected children of certain ages and measured their heights, then age would be the independent variable, and height the dependent variable. (B3)

**indeterminacy\*** This is a fundamental property of a quantum system. The positions and speeds of electrons in atoms cannot be specified precisely. They are



intrinsically indeterminate and can only be described in terms of probability. (B7)

**inertia\*** The 'reluctance' of a body to accelerate (see acceleration). Mass is a measure of inertia. (B3)

**infinity** Larger than any number you can think of. (B11)

**inflation\*** The name given to a theory which describes the behaviour of the Universe at times between about  $10^{-36}$  s and  $10^{-32}$  s after the Big Bang. During this interval it is proposed that distances within the Universe increased by an extraordinarily huge factor (at least  $10^{50}$ ). Inflation is believed to be caused by the way in which the strong interaction and the electroweak interaction became distinct. If inflation is correct, it predicts that we live in a flat Universe. (B11)

**infrared radiation\*** A subrange of electromagnetic radiation. It lies between the long wavelength limit ( $0.7\text{ }\mu\text{m}$ ) of visible radiation and the microwave subrange. (B2)

**inheritance\*** The principle by which offspring tend to resemble their parent(s) more than they do other members of the same species as a consequence of inheriting genetic material during the course of reproduction. Inheritance is one of the necessary and sufficient conditions for natural selection to occur. (B4)

**inherited characters\*** Characters that are passed on from generation to generation by inheritance. (B9)

**inner core** The solid inner part of the Earth's core. (B3)

**inorganic chemistry\*** The branch of chemistry that deals with the chemistry of all the elements and their compounds, apart from the compounds of carbon. (B8)

**inorganic phosphate\*** See  $\text{P}_i$ .

**insoluble\*** A substance that does not dissolve in a liquid is said to be insoluble in that liquid. (B1)

**insulator** See electrical insulator.

**intensity\*** (of earthquakes) See earthquake intensity.

**intensity\*** (of radiation) The power per unit area delivered by light (or any other electromagnetic radiation) in a small range of photon energy. (B7)

**intercept** The point at which a straight-line graph crosses the vertical axis. (B7)

**interglacial periods\*** Relatively warm periods of time within an ice age when glaciers and ice-caps are at their minimum extent. We are currently living in an interglacial period. Compare with glacial periods. (B2)

**intermediate\*** (metabolism) An organic compound that is a partial breakdown product formed in one metabolic pathway in the cell and which may be used in another pathway. (B9)

**intermediate-focus earthquake** An earthquake with a focus at a depth of 70–300 km. (B3)

**intermembrane space\*** (mitochondria) The space between the inner and outer membranes of the mitochondria. (B9)

**intermolecular interactions\*** The interactions between molecules that bind them together in the liquid and solid states. The main types discussed in S103 are hydrogen bonds and London interactions. (B8)

**internal energy\*** The sum of the kinetic energy and potential energy of all the molecules in a substance. The internal energy can be increased by supplying heat or by doing work. (B5)

**interphase\*** The collective term for the three phases of the cell cycle known as growth I, replication and growth II. (B4)

**interpolation\*** The process of reading between points plotted on a graph, in order to find the value of one or both of the plotted quantities at intermediate positions. (B1)

**interstellar matter** The thin gas and dust between the stars. (B3)

**intertidal zone** The area of the seashore between the levels reached by high and low tides. (B4, A9.1)

**intrinsic rate of natural increase ( $r$ )\*** The maximum rate at which a population can increase in size. Compare with carrying capacity. (B4)

**introns\*** Non-coding sequences of bases within a split gene which are interspersed with exons. The entire gene undergoes transcription into an mRNA molecule, but the introns are subsequently removed and the exons remaining are joined together to give mature mRNA, which undergoes translation into a functional protein. (B9)

**intrusive\*** The term applied to igneous rocks formed by cooling and crystallization of magma below the ground surface. Intrusive rocks, such as granite and gabbro, are characterized by coarse grain size due to slow cooling. Bodies of intrusive igneous rock are known as intrusions. Contrast with extrusive. (B10)

**inverse** The inverse of a value is found by dividing the value into one. For example the inverse of 4 is  $1/4$  which is 0.25; the inverse of  $5\text{ km s}^{-1}$  is  $1/(5\text{ km s}^{-1})$ , which is  $0.2\text{ s km}^{-1}$ . (B3)

**inverse proportionality\*** If two quantities are related such that an increase by a factor of two in one results in a decrease by a factor of two in the other, they are said to be inversely proportional to each other. Specifically, if  $y$  is inversely proportional to  $x$ , this may be written as  $y \propto \frac{1}{x}$  or as the equation  $y = \frac{k}{x}$ , where  $k$  is a constant.

Compare with proportional to. (B7)

**inverse square law** Any equation in which the size of one quantity is inversely proportional to the square of another quantity. Coulomb's law, Newton's law of gravity, and the relationship between brightness and distance are all examples of inverse square laws. (B11)

**ion\*** An atom or a molecule or a chemical group that has lost or gained one electron or more, leaving it with a positive or negative electric charge, respectively (e.g.  $\text{Na}^+$  and  $\text{F}^-$ ). (B6)

**ion product of water\*** A mathematical quantity, symbol  $K_w$ , obtained by multiplying together the concentrations of aqueous hydrogen and hydroxide ions in an aqueous solution at equilibrium. Thus  $K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$  and at  $25\text{ }^\circ\text{C}$ , it has the value  $1.0 \times 10^{-14}\text{ mol}^2\text{ litre}^{-2}$ . (B8)

**ionic bonding\*** A model of chemical bonding in which appropriate chemical compounds are regarded as collections of ions, the principal binding forces being the



attractions between the unlike electric charges on those ions. (B8)

**ionic compound\*** A compound whose properties are such that it can be usefully thought of as a collection of ions held together by the attractive forces between unlike electric charges. (B8)

**ionic interaction\*** The attraction between oppositely charged groups either within a molecule or in two different molecules. One of the three types of weak bond which help to maintain the higher-order structure of biopolymers. (Ionic interactions are very much weaker than ionic bonding because the pairs of oppositely charged groups occur *singly* and are relatively *far apart*.) (B9)

**ionization\*** The process by which an atom (or existing ion) is turned into an ion (or more positive ion) when one or more electrons are removed from it. (B7)

**ionization energy\*** The energy required in order to remove an electron from an atom or from an existing ion. See ionization. (B7)

**irregular galaxy** A galaxy that has a ragged shape: it has no disc or spiral arms. (B3)

**island arc\*** The chain of volcanic islands on the over-riding plate at a subduction zone where two plates of oceanic lithosphere converge. An island arc lies parallel to an ocean trench. (B3)

**island-arc accretion\*** The increase in size of a continent by collision and joining with an island arc. (B3)

**isomers\*** Different molecules are isomers if they have the same molecular formula but different structural formulae. (B8)

**isotope\*** Atoms with the same number of protons in their atomic nuclei, but different numbers of neutrons are called isotopes. Because they have the same number of protons, they have the same atomic number and are atoms of the same chemical element. But because of the different number of neutrons, they differ in mass number. (B6)

**iteroparity\*** (adjective: iteroparous) An iteroparous species is capable of reproduction several times in the course of its life history; it is said to display iteroparity. Compare with semelparity. (B4)

**joule\*** In SI units, the unit of energy, with the symbol J. (B2)

**K\*** See carrying capacity.

**k-value\*** A number calculated for a mortality factor which represents 'how much death' occurs at a particular stage of the life cycle. It is based on the ratio between the number of individuals alive at one stage of the life cycle and the number that survive to the next stage. The bigger the k-value, the greater the mortality. (B9, A1.1)

**karyotype\*** The array of chromosomes that a particular species possesses. (B9)

**kelvin\*** In SI units, the unit of temperature, with the symbol K, used to measure temperatures on the absolute temperature scale. One kelvin is the same size as the degree on the Celsius scale, so there are 100 K between the normal freezing and boiling temperatures of water. (B5)

**Kelvin scale** See absolute temperature scale.

**key** (in map or diagram) A list of colours, symbols, abbreviations, etc. used in a map or diagram, together with their meanings. (B1)

**key mortality factor\*** The mortality factor whose pattern of annual variation in k-value most closely parallels the pattern of change in k<sub>total</sub> over a period of years. The size of the population is influenced more by the key mortality factor than by any other mortality factor. Key mortality factors are usually density independent. (B9, A1.1)

**kilo\*** A prefix to a unit, which means 'one thousand'; for example, 1 kilogram, abbreviated to 1 kg, is 1 000 grams. (B1)

**kilogram\*** In SI units, the unit of mass, abbreviated to kg. (B1)

**kinetic energy\*** Energy associated with motion of an object. An object with mass *m* moving at speed *v* has kinetic energy  $E_k = \frac{1}{2}mv^2$ . (B5)

**kingdom\*** The level of taxonomic classification between domain and phylum, e.g. the kingdom Animalia is part of the domain Eukarya and comprises all the animals. (B4)

**k<sub>total</sub>\*** See pre-reproductive generation mortality.

**lactate** The compound produced when pyruvate is reduced by NAD<sub>2</sub>H, a reaction that occurs in anaerobic respiration in muscles. (B9)

**landslide** A rapid movement of earth materials down a slope, which can be triggered by an earthquake. (B3)

**larva\*** (plural: larvae) Principal feeding and growth stage in the life cycle of many insects; sometimes called a caterpillar or grub. (B4, A7.1)

**latent heat\*** The energy required to cause a change in the state of a substance from solid to liquid, from solid to gas or from liquid to gas, or the energy released as a consequence of the reverse change in state. (B2)

**latent heat of vaporization\*** The amount of energy, usually in the form of heat, that has to be supplied to convert one unit of mass of a substance from the liquid state to the gaseous (vapour) state, or conversely the heat released when one unit of mass of gas condenses to a liquid. The symbol used for latent heat is *L*, and its SI unit is J kg<sup>-1</sup>. (B5)

**latitude\*** Part of the specification of the position of a point on the Earth's surface: the distance north or south of the Equator measured in degrees. A line of latitude is an imaginary circle on the surface of the Earth. All points on a particular line of latitude are the same distance from the Equator. See also longitude. (B2)

**lava\*** Molten rock extruded from a volcano at the surface of the Earth. The term is also used for the solid material formed in this way. (B3)

**law of conservation of energy\*** See conservation of energy.

**law of conservation of mass\*** See conservation of mass.

**law of segregation\*** (Mendel's law) The two copies of a gene undergo segregation (become separated) from each other during gamete formation, so that one half of the gametes carry one copy of the gene and the other half of the gametes carry the other copy. (B9)



**Le Chatelier's principle\*** This states that when a system in chemical equilibrium is subject to an external constraint, the system responds in a way that tends to oppose the effect of the constraint. (B8)

**LEP2** The large electron-positron collider mark 2, a particle accelerator at CERN. (B11)

**lepton\*** A fundamental particle, the matter counterpart of an antilepton. There are six types (flavours) of lepton: the electron ( $e^-$ ), the muon ( $\mu^-$ ), the tauon ( $\tau^-$ ), the electron neutrino ( $\nu_e$ ), the muon neutrino ( $\nu_\mu$ ), and the tauon neutrino ( $\nu_\tau$ ). (B7)

**levels of explanation\*** Different perspectives on a biological phenomenon, e.g. a clutch of eggs can be thought about in developmental, metabolic, reproductive or ecological terms. (B4)

**Lewis structure\*** A diagram that shows how the outer electrons of the atoms in a chemical substance are shared to create electron-pair bonds, in accordance with the theory of covalent bonding. (B8)

**LHC** The large hadron collider, a particle accelerator at CERN. (B11)

**life cycle\*** The repeated alternation of growth and reproduction in organisms. (B4)

**life history\*** The full schedule of birth, growth, reproduction (possibly repeated) and death in an individual of a species. Compare with life cycle. (B4)

**light** See visible radiation.

**light reactions\*** Those steps in photosynthesis that can take place only in the light. Energy from sunlight, absorbed by chlorophyll in the internal membranes of the chloroplasts, is used to form ATP from ADP and  $P_i$  and NADP.2H from NADP and water, with the consequent production of oxygen. The products of the light reactions are used in the dark reactions of photosynthesis. (B9)

**light-year** The distance that light can travel in one year. Equal to about  $10^{16}$  m or about one-third of a parsec. (B11)

**limestone** A sedimentary rock, composed largely of calcium carbonate (calcite), that is formed typically by the accumulation on the ocean floor of the shells or skeletal remains of marine organisms. See also carbonate rocks. (B3)

**linear-chain alkane\*** A saturated hydrocarbon that has a linear backbone of carbon atoms, e.g. propane,  $\text{CH}_3\text{—CH}_2\text{—CH}_3$ . Contrast branched-chain alkane. (B8)

**linear-chain hydrocarbon** A hydrocarbon that has a simple linear chain of carbon atoms (see linear-chain alkane). (B8)

**link reaction\*** A reaction which forms Stage 2 of glucose oxidation, in which pyruvate is converted into acetyl, carbon dioxide and NAD.2H. It occurs in the mitochondrial matrix. (B9)

**linkage\*** The association of genes on the same chromosome. (B9, A8.4)

**linkage map** See genetic map.

**lipid** A varied group of hydrophobic organic compounds, insoluble in water and soluble in hydrophobic solvents. Lipids are the fatty components of

living organisms; solid lipids are described as fats and liquid lipids as oils. (B9)

**liquid** See liquid state.

**liquid state\*** One of the three states in which substances can exist; the other two are solid and gas. (B1) In the liquid state the particles that make up a substance are close enough to be attracted to each other, but they are not arranged in a regular way. The particles move around, swapping positions. (B2)

**lithification\*** The collective term for the processes of compaction and chemical change that transform loose sediment into rock. (B2) The process of lithification includes cementation and often accompanies burial. (B10)

**lithosphere\*** The rigid outer layer of the Earth, which includes the crust and the uppermost part of the mantle. Oceanic lithosphere is lithosphere with oceanic crust. Continental lithosphere is lithosphere with continental crust. (B3)

**lithospheric plate\*** An area of lithosphere, the edges of which are defined by a seismic zone. This is usually abbreviated to plate. (B3)

**litre\*** A unit of volume equal to the volume of a cube that has 10 cm sides. Hence 1 litre =  $1\,000\text{ cm}^3$  and  $1\,000\text{ litres} = 1\text{ m}^3$ . Abbreviated to l. (B1)

**locus\*** The specific position on a chromosome where a gene is located. (B9)

**London interactions\*** A type of cohesive force that occurs between all molecules in the liquid and solid states. The strength of London interactions increases with increasing relative molecular mass. (B8)

**longitude\*** Part of the specification of the position of a point on the Earth's surface. A line of longitude is an imaginary semicircle on the surface, that runs from one pole to the other pole. The line of zero longitude passes through Greenwich in London. Other lines of longitude are specified by the angle in degrees east or west of the line of zero longitude. See also latitude. (B2)

**look-back time** When observing a distant galaxy, the light (and other electromagnetic radiation) which is measured, has taken a significant amount of time to cross the intervening space between the galaxy and us. The look-back time quantifies how far into the past we are seeing when observing a particular distant galaxy. (B11)

**Love wave\*** A type of seismic wave; the faster surface wave. This moves the ground surface horizontally. (B3)

**luminosity\*** ( $L$ ) The amount of power, in watts, emitted by a luminous object such as a star or galaxy, in the form of light or other electromagnetic radiation. It is related to the observed brightness  $F$  of an object, situated a distance away  $r$ , by the equation  $L = 4\pi r^2 F$ . (B11)

**MaCHOs** Massive compact halo objects, postulated as existing in the outer haloes of every galaxy and contributing to the dark matter they contain. They may consist of failed stars which were never able to undergo nuclear fusion in their cores. (B11)

**macromolecule** A general name for a very large molecule, often used interchangeably with the more specific term polymer. (B9)



**mafic\*** Term used to describe the dark-coloured minerals of igneous rocks, especially minerals that contain magnesium and iron. Dark igneous rocks rich in mafic minerals are known as mafic rocks. (B10)

**magma\*** Molten rock. When magma solidifies on cooling, it forms an igneous rock. (B3)

**magma chamber\*** A large chamber full of magma beneath a volcano. (B3)

**magnetic anomaly\*** A difference between the magnetism measured at a point on the Earth's surface and the magnetism expected in the absence of any local disturbances, at that point. (B3)

**magnetic constant** The constant of proportionality ( $k_m$ ) in the magnetic force law has an exact value of  $1 \times 10^{-7} \text{ N s}^2 \text{ C}^{-2}$ . Maxwell's laws of electromagnetism showed that the speed of light  $c$  (and other electromagnetic radiation) is related to the Coulomb constant  $k_e$  and the magnetic constant by

$$c^2 = \frac{k_e}{k_m} \quad (\text{B11})$$

**magnetic force** ( $F_m$ ) The force produced by an electric current (i.e. a moving electric charge) or by a varying electric force. See magnetic force law. (B11)

**magnetic force law** Two parallel wires carrying electric currents  $I_1$  and  $I_2$  flowing in the same (or opposite) directions and separated by a distance  $r$ , will attract (or repel) each other with a magnetic force exerted by the entirety of one wire on a length  $L$  of the other given by  $F_m = k_m \frac{2I_1 I_2 L}{r}$ . The constant  $k_m$  is known as the magnetic constant. (B11)

**magnetism** The magnetic phenomena associated with any object having the properties of a magnet. The Earth's magnetism causes a compass needle to point towards the North Pole. (B3)

**magnitude\*** The numerical value of a quantity. Magnitude does not take account of any direction associated with the quantity or of whether the quantity has a positive or negative value. (For magnitude of an earthquake see earthquake magnitude.) (B3)

**maintenance** Production of new cells and cell chemicals to replace those broken down in turnover. (B9)

**major planet\*** One of the nine most massive bodies forming the Solar System, in orbit around the Sun. (In fact, some of the major planets have a natural satellite (or more than one) which is more massive than the outermost major planet, Pluto.) (B3)

**mantle\*** The seismic layer of the Earth beneath the crust and Mohorovičić discontinuity (Moho). The mantle has a higher density and higher seismic wave speeds than the crust, and is composed of peridotite. (B3)

**marine magnetic anomaly\*** A positive or negative linear magnetic anomaly on the oceanfloor. Marine magnetic anomalies occur symmetrically about a mid-ocean ridge. They can be dated and thus enable sea-floor spreading rates to be calculated. (B3)

**mass\*** The quantity of matter in an object. In SI units, the unit of mass is the kilogram. (B1) The mass of a body determines its acceleration when it is acted on by an unbalanced force; the greater the mass (for a given

unbalanced force) the smaller the acceleration. The quantitative relationship is given by Newton's second law of motion  $F = ma$ . Mass is a measure of the inertia of a body. Mass also determines the magnitude of the force of gravity acting on a body. (B3) This gravitational force is also known as the weight of the body. Mass and energy are related by Einstein's equation  $E = mc^2$ . (B5)

**mass excess\*** A useful quantity when deciding whether a radioactive decay will occur and, if it does, how much energy will be released. Radioactive decay processes will only occur if the mass excess of the products is less than the mass excess of the parent nuclide. (B7, A5.1)

**mass extinction\*** A geologically rapid, major reduction in the diversity of life on a global scale. The most severe mass extinctions of the Phanerozoic were in the late Ordovician, late Devonian, late Permian, late Triassic, and late Cretaceous. (B10)

**mass number  $A$ \*** The number of nucleons (protons and neutrons) in the nucleus of an atom. It has the value of the relative atomic mass of the isotope, rounded to the nearest whole number. (B6)

**mathematical model** A model that consists of one or more mathematical equations that are used to calculate a quantity (or quantities) of interest. (B2) In biology for example, the outcome of a breeding experiment, such as the one carried out in maize, can be determined by the law of probability. (B9)

**matrix\*** (mitochondria) The fluid-filled region inside the inner mitochondrial membrane; here the link reaction and TCA cycle take place. (B9)

**mature mRNA\*** An mRNA molecule that consists only of exons produced by transcription, the transcribed non-coding sequences, or introns, having been removed. Translation of mature mRNA produces a functional protein. (B9)

**Maxwell's laws of electromagnetism** A theory unifying the phenomena of electric and magnetic interactions, as they were understood towards the end of the 19th century. The theory explains that stationary electric charges give rise to electric forces, that moving electric charges (i.e. electric currents) give rise to magnetic forces, that a changing magnetic force produces an electric force, and that a changing electric force produces a magnetic force. A prediction of Maxwell's theory was the existence of electromagnetic radiation which travels through space with a speed given

by  $c = \sqrt{\frac{k_e}{k_m}}$  where  $k_e$  is the Coulomb constant and

$k_m$  is the magnetic constant. Compare with quantum electrodynamics. (B11)

**mean\*** The sum of a series of measurements divided by the number of those measurements. (B2)

**mean annual precipitation\*** The mean value of a series of measurements of the total precipitation during a year, averaged over a series of years. (B2)

**mean surface temperature\*** The mean value of surface temperature, based on a number of measurements at the same place or a range of places (for example, the global mean surface temperature), and over a particular length of time, such as one day, one year



(annual mean surface temperature) or 30 years (30-year mean surface temperature). (B2)

**mega\*** A prefix to a unit, which means 'one million' or  $10^6$ ; for example, one megawatt is one million watts,  $1 \text{ MW} = 10^6 \text{ W}$ . (B2)

**meiosis** The type of cell division in which the number of chromosomes in the nucleus of each progeny cell is half the number in the parent cell (i.e. progeny cells possess a haploid rather than diploid set of chromosomes). During the course of meiosis each chromosome ends up in a different progeny cell to its partner. Meiosis plays a key part in sexual reproduction (compare with mitosis). (B4) Nuclear division that results in a halving of the chromosome number (and thus the genetic material), and is the necessary prelude to the formation of gametes. Each of the two divisions of meiosis is divided into stages; division I: prophase I, metaphase I, anaphase I and telophase I; division II: prophase II, metaphase II, anaphase II and telophase II. (B9)

**melting\*** The transformation of a solid into a liquid. It involves a transition from a state in which the particles that make up the substance occupy specific positions to one in which they can swap positions. (B2)

**membrane** A structure that separates the rest of a cell from its surroundings or part of a cell from the rest of the cell. See cell membrane and nuclear membrane. (B4)

**meson\*** A subatomic particle composed of a quark and an antiquark. A type of hadron. Examples of mesons include the pion. (B7)

**Mesozoic\*** The middle era of the Phanerozoic, consisting of the Triassic, Jurassic and Cretaceous Periods. It lasted from 248 to 65 Ma ago. (B10)

**messenger RNA\*** See mRNA.

**metabolic pathway\*** A sequence of enzyme-catalysed reactions in the cell, which forms part of catabolism or biosynthesis. The many different and interlinked pathways constitute metabolism as a whole. (B9)

**metabolism\*** All the chemical transformations that take place in an organism. Metabolism is one of the three attributes of life. (B4) The sum of catabolism and biosynthesis. (B9)

**metals\*** A class of substances to which most of the chemical elements belong. They are good conductors of heat and electricity in the solid and liquid states, their electrical conductivity decreases with increasing temperature, and bulk samples often have a lustrous appearance. (B6)

**metamorphic belt** An area of exposed regional metamorphic rocks, often occurring within mountain belts. Metamorphic grade usually increases towards the centre of the belt where uplift tends to be greatest. (B10)

**metamorphic grade\*** The general conditions of metamorphism to which rocks have been subjected. Both the metamorphic conditions and the rock produced are said to be high grade when high temperatures and pressures are involved; low grade when low temperatures and pressures are involved. (B10)

**metamorphic rock\*** A rock that has had its texture and/or mineral composition changed by the action of heat and/or pressure (usually both). A metamorphic rock

can be derived from a sedimentary rock, an igneous rock, or a pre-existing metamorphic rock. Metamorphic rocks have an interlocking crystalline texture and often display some form of mineral banding or alignment. (B3)

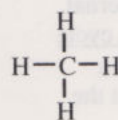
**metamorphism** The process by which the texture and/or mineral composition of a rock are changed by the action of heat and/or pressure. (B3)

**metaphase\*** A phase of mitosis in which each chromosome becomes aligned across the middle of the cell. (B4)

**meteor** A small body that enters the Earth's atmosphere where it is heated by air resistance and becomes luminous. If any of it survives to reach the Earth's surface it is called a meteorite. A meteor is often a very small minor planet; others are comet fragments. (B3)

**meteorite\*** An extraterrestrial rock that has fallen to the Earth's surface. See also meteor. (B3)

**methane** An alkane with the molecular formula  $\text{CH}_4$  and the structural formula



(B8)

**methyl group** The simplest hydrocarbon group, consisting of a single carbon atom with three hydrogen atoms attached and one bond to another atom, often another carbon atom. It is usually abbreviated as  $-\text{CH}_3$  or  $\text{CH}_3-$ . (B8)

**metre\*** In SI units, the unit of length, abbreviated to m. (B1)

**mica\*** A sheet silicate mineral found in many igneous, sedimentary and metamorphic rocks. Muscovite is a pale-coloured variety (silvery-grey) that contains little iron or magnesium. Biotite is a dark-coloured variety (dark brown to black) that contains appreciable iron and/or magnesium. (B10, A4.2)

**micro\*** A prefix to a unit, which means 'one-millionth'; for example, a micrometre is one-millionth of a metre,  $1 \mu\text{m} = \frac{1}{1\,000\,000} \text{ m} = 10^{-6} \text{ m}$ . The symbol for micro is the Greek letter  $\mu$  (mu), pronounced 'mew'. (B2)

**mid-ocean ridge\*** A broad ridge a few thousand kilometres across and 2–3 km high on the ocean floor, extending for many thousands of kilometres. Mid-ocean ridges do not always lie in the centres of oceans. A mid-ocean ridge is a divergent plate boundary. (B3)

**migration** The movement of individual organisms between populations, which leads to mixing of genes or gene flow. (B9)

**Milky Way\*** A faint band of light that arches across the sky, and that consists of the stars and interstellar matter in the Galactic disc. (B3)

**milli\*** A prefix to a unit, which means 'one-thousandth'; for example, one millimetre is one-thousandth of a metre,  $1 \text{ mm} = \frac{1}{1\,000} \text{ m}$ . (B1)



**mineral\*** A solid object, formed by natural processes, whose chemical composition lies within narrow limits such that each constituent atom fits together with its neighbours in a regular three-dimensional pattern. Because of this, each type of mineral forms a crystal with a characteristic shape. (B3)

**minor planet** A body made of rocky materials in orbit around the Sun, that is much less massive than any major planet. Often called an asteroid. (B3)

**missing mass\*** If we live in a flat Universe, then the amount of visible matter which is observed (in the form of stars, galaxies, gas and dust) plus the amount of dark matter, is not sufficient to account for the critical density of matter that must exist in the Universe. The difference is described as missing mass and must be in the form of particles which are totally unlike the familiar protons, neutrons or electrons from which the rest of the Universe is composed. Such particles are often described as WIMPs. (B11)

**mitochondria\*** (singular: mitochondrion) Organelles that occur in most eukaryote cells, and vary in size and shape. They have an outer membrane and an internal, highly folded membrane within them. The TCA cycle and the link reaction occur in the matrix. Electron transport and oxidative phosphorylation occur at the inner membrane. (B9)

**mitosis\*** The type of cell division that takes place during growth and during repair of parts of the body. Mitosis produces diploid progeny cells, in each of which every chromosome is identical to a chromosome possessed by the parent cell. Mitosis occurs in a sequence of stages, termed prophase, metaphase, anaphase and telophase. Compare with meiosis. (B4)

**mixture\*** A mixture contains more than one substance; for example, air is a mixture since it contains nitrogen, oxygen, argon, carbon dioxide, water, etc. (B2)

**model** A simplified representation of the real world that aids understanding by focusing on some particular aspects of reality. (B2)

**Mohorovičić discontinuity (Moho)\*** The seismic discontinuity between the crust and mantle of the Earth. (B3)

**mol** Abbreviation for mole used in units such as mol litre<sup>-1</sup>. (B8)

**molar bond enthalpy\*** The enthalpy change associated with the breaking of a mole of chemical bonds of a specified type, such as the dissociation of a mole of molecules each of which contains a single bond between two atoms. (B8)

**molar mass\*** The mass of one mole of a substance. (B6)

**mole\*** An amount of a substance. Its mass is obtained by adding up the relative atomic masses of the atoms in the formula unit, and following the resulting number by the symbol for the gram. (B6)

**molecular formula\*** A concept that can be applied to substances that consist of discrete molecules. Gases are examples of such substances. The molecular formula is a representation, using chemical symbols, of the numbers of the different types of atom contained in one molecule of such a substance. For example, the gas ethane has the molecular formula C<sub>2</sub>H<sub>6</sub>. (B6) Molecules can also be

identified in solids, which can then be given a molecular formula. Thus solid iodine and solid sulfur have the molecular formulae I<sub>2</sub> and S<sub>8</sub>, respectively. (B8)

**molecular mass** See relative molecular mass.

**molecular substance\*** A substance whose properties are such that it can be usefully thought of as a collection of discrete molecules, the binding within the molecule itself being strong and covalent, and the binding between molecules being weak (see intermolecular interactions). (B8)

**molecule\*** The smallest particle of a substance. Molecules are made from atoms. For example, water is made up of water molecules that consist of an oxygen atom joined by two chemical bonds to two hydrogen atoms. (B2) In gases, the tiny identical particles, consisting of one or more atoms, that make up the gas and move about as a unit. If the molecules contain more than one atom, those atoms do not part company during this motion. The average distance between the molecules in gases is very much greater than the size of the molecules themselves. (B6) Molecules can also be identified in many solids (e.g. iodine and sulfur) and liquids because the distance that separates them is significantly larger than the distance between atoms within the molecule. (B8)

**mollusc\*** A member of the phylum Mollusca, among which are three classes that are particularly abundant and diverse today and in the fossil record: bivalves, gastropods, and cephalopods. (B10)

**monatomic ion\*** An ion formed from a single atom by the loss or gain of electrons. (B6)

**monochromatic\*** (light) Light that has a single colour. It therefore refers to photons of a single energy, or light of a single wavelength or frequency. (B7)

**monomer\*** A molecule that, under the correct conditions, can link together with others to form larger molecules called polymers. A monomer must be capable of forming two or more bonds to other monomers. (B8)

**monomer unit\*** The basic repeating unit of a polymer chain; it is derived from a monomer. (B8)

**monosaccharide\*** A sugar that cannot be hydrolysed to anything simpler and which is a sweet, water-soluble carbon compound with several hydroxyl (OH) groups. Common monosaccharides are glucose, fructose and ribose. (B9)

**Moon** The Earth's only natural satellite. (B3)

**moraine\*** An accumulation of sediment including till, that has been deposited from glaciers or ice-sheets and which forms mounds, sheets and ridges. (B2)

**morphology** An organism's overall structure and appearance. (B4)

**mortality factor\*** A particular cause of death of an organism. It may operate at a particular stage of an organism's life cycle, e.g. predation of a holly leaf miner larva by a bird. (B4)

**mortality rate\*** The percentage of a population that dies over a particular period of time. Mortality rate can be calculated for a single generation (the number of individuals that fail to survive long enough to reproduce, as a percentage of the number of fertilized eggs that were produced at the start of that generation) or for a particular stage of the life cycle (the number of



individuals that fail to survive to the end of a particular stage of the life cycle, as a percentage of the number of individuals that survived to the beginning of that stage of the life cycle). (B9, A1.1)

**mountain belt\*** A long, linear, high-altitude area of the Earth. (B3)

**mountain-building\*** The process by which mountain belts are formed. It usually results from convergence of lithospheric plates and may involve continental collision. See also orogeny. (B10)

**mRNA\*** A single-stranded molecule of RNA produced by the transcription of DNA. A particular mRNA molecule carries the genetic code for the precise sequence of amino acids that make a polypeptide. (B9)

**mud\*** Very fine-grained sediment (grains <0.06 mm diameter), often composed of clay minerals, which feels smooth when rubbed between fingers. (B10)

**mudstone\*** A fine-grained sedimentary rock, formed by accumulation of mud that was subsequently buried and compacted. (B10)

**multicellular organism\*** An organism consisting of more than one cell (usually many more). (B4)

**multiple alleles\*** The existence of several known alleles of a gene, such as the *A*, *B* and *O* alleles of the ABO blood group system, although only two gene copies are present in an individual. (B9)

**muon ( $\mu^-$ )** A fundamental particle (a lepton) with electric charge  $-e$  which is similar to an electron but with a mass about 200 times heavier. Its antiparticle is called the antimuon ( $\mu^+$ ). (B7)

**muon neutrino ( $\nu_\mu$ )** A fundamental particle (a lepton) with zero electric charge which may have zero mass. Its antiparticle is called the muon antineutrino ( $\bar{\nu}_\mu$ ). (B7)

**mutation\*** An alteration in an organism's genetic material (or DNA) which may be copied to that organism's offspring. The term is also used to refer to any change in the morphology, behaviour or metabolism of an organism which may be inherited because it is at least partly determined by the genetic material. (B4)

**NAD\*** (nicotinamide adenine dinucleotide) A coenzyme that carries hydrogen atoms. Its reduced form is written as NAD.2H. It is used in reactions of catabolism such as those of the glucose oxidation pathway. (B9)

**NADP\*** (nicotinamide adenine dinucleotide phosphate) A coenzyme that transfers hydrogen atoms in reactions of biosynthesis, such as in the dark reactions of photosynthesis. Its reduced form is written as NADP.2H. It is very similar to the coenzyme NAD which is used mainly in reactions of catabolism. (B9)

**nano\*** A prefix to a unit, which means 'one-thousand-millionth' or  $10^{-9}$ ; for example, a nanometre is  $10^{-9}$  metre ( $1\text{ nm} = 10^{-9}\text{ m}$ ). (B7)

**natural satellite** A natural (i.e. not manufactured) body in orbit around one of the planets, and less massive than the planet. (B3)

**natural selection\*** The process proposed originally by Charles Darwin as being largely responsible for biological evolution. Where variation between individuals exists and there is a struggle for existence,

then, on average, organisms that show better adaptation to their environment survive longer and leave more offspring (i.e. they have greater fitness) than those that are less well adapted. Over time, natural selection may change the characteristics of the population, and possibly of an entire species, provided there is inheritance of the favourable adaptation(s). (B4)

**nectary** The part of a flowering plant that produces nectar. (B4, A9.1)

**negative feedback\*** This occurs when an increase (or decrease) in one quantity causes changes to other quantities that eventually lead to a decrease (increase) in the original quantity. See also positive feedback. (B2)

**net primary productivity (NPP)\*** The increase in autotroph biomass over a specified time and in a specified area or volume or in a specified food chain, food web or ecosystem. This is equivalent to the amount of solar energy that is trapped by photosynthesis, but not lost through respiration. Compare with gross primary productivity (GPP). (B4, A7.1)

**neutral** (electrically) Objects with no electric charge, or with equal amounts of positive and negative charge, are electrically neutral. (B5)

**neutral mutations** Alleles that have neither a positive nor a negative effect on the relative fitness of the individuals that carry them. (B9)

**neutral solution\*** An aqueous solution in which the concentrations of aqueous hydrogen ions and hydroxide ions are equal. At  $25^\circ\text{C}$  their concentrations are each  $1.0 \times 10^{-7}\text{ mol litre}^{-1}$ . See also pH scale. (B8)

**neutralization\*** A chemical reaction marked by the mutual destruction of an acid and a base (most especially a basic hydroxide) and the formation of a salt. Such neutralization reactions are often conducted in aqueous solution. (B6)

**neutron\*** A particle with no electric charge and a mass very close to that of the proton. As with the proton therefore, the relative atomic mass of a neutron is very close to one on the international scale of relative atomic masses. Neutrons are found in each atomic nucleus except that of hydrogen,  $^1\text{H}$ . (B6) A neutron is a baryon, with the quark composition (udd). It has a mass of about  $1\text{ GeV}/c^2$ . (B7)

**neutron number (*N*)** The number of neutrons in a nuclide. (B7, A5.1)

**newton\*** In SI units, the newton is the unit of force, symbol N, and is equivalent to  $\text{kg m s}^{-2}$ . (B3)

**Newton's first law of motion\*** This law states that an object remains at rest or moves in a straight line at constant speed unless it is acted on by an unbalanced force. (B3)

**Newton's law of gravity\*** This law states that the gravitational force that one object exerts on another increases when the mass of either object increases, or when the distance between the two bodies decreases. The direction of the force on one object is towards the other object. (See also gravity.) (B3) Two particles of mass  $m_1$  and  $m_2$ , separated by a distance  $r$ , will attract each other with a gravitational force that is inversely proportional to the square of their separation, and proportional to the product of the masses,



$F_g = G \frac{m_1 m_2}{r^2}$ . The constant of proportionality  $G$  is

known as the gravitational constant. (B11)

**Newton's second law of motion\*** This law states that the magnitude  $F$  of the unbalanced force on an object with a mass  $m$  is related to the magnitude  $a$  of the acceleration of the object by the equation  $F=ma$ , the acceleration being in the same direction as the unbalanced force. (B3)

**Newton's third law of motion** This law states that if an object A exerts a force on object B, then object B exerts a force on object A that has the same magnitude, but is in the opposite direction to that of the force of A on B. (B3)

**nitrogen fixation** The process by which nitrogen gas is converted by certain bacteria into nitrogen-containing compounds, such as sodium nitrate, that can be taken in by plants. (B8)

**nitrogen-fixing bacteria** Bacteria that are able to fix nitrogen, that is convert nitrogen from the air into compounds that can be used by plants as a source of nitrogen. (B8)

**noble gas configuration** The electron configurations of the noble gas atoms. With the exception of helium whose atom has the configuration  $1s^2$ , they have eight electrons in their outermost shell. Elementary theories of chemical bonding depend on the idea that these configurations are especially stable, and that other elements try to attain them when they react to form chemical compounds. (B8)

**noble gases\*** The gaseous chemical elements helium, neon, argon, krypton, xenon and radon, which are all placed in Group 0 of the Periodic Table. They are so named because of their marked reluctance to 'lower' themselves by combining with other chemical elements to form chemical compounds. (B6)

**noble metals** Metals, such as gold, silver and platinum, that show a marked reluctance to combine with other elements to form compounds. (B6)

**non-bonded electron pair\*** When atoms of the non-metallic elements in Groups V–VII of the Periodic Table are covalently bonded in molecules, they do not need to share all their outer electrons to achieve a noble gas configuration. These unshared electrons (which are always in pairs) are called non-bonded electrons. (B8)

**non-metal\*** A term usually reserved for those chemical elements that are very poor electrical conductors in the solid and liquid states. A number of them are gases at room temperature. When solid or liquid, they tend to have a matt rather than a lustrous appearance. (B6)

**non-template strand\*** The DNA strand that is *not* used as a template for RNA synthesis during transcription. The DNA strand used as the template for RNA synthesis is termed the template strand. (B9)

**normal distribution\*** A symmetrical bell-shaped distribution of organisms or objects where the majority fall within the middle of the range, with few at the two extremes. Quantitative characters, such as height in humans, show such a pattern of distribution; the majority of individuals fall around the mean height, and there are very few small individuals and very few large individuals. (B9)

**normal polarity\*** When the Earth's magnetism is such that a compass needle points towards the North Pole (as at present), the Earth's magnetism is said to have normal polarity. Contrast reversed polarity. (B3)

**NPP** See net primary productivity.

**nuclear bulge** A bulge of stars and interstellar matter at the centre (nucleus) of the Galactic disc. (B3)

**nuclear fission** The process whereby an unstable atomic nucleus splits into two roughly equal halves. Energy and some free neutrons are released. Fission is most likely to happen in nuclei with a large mass number. (B7, A5.1)

**nuclear fusion\*** The fusing together of two atoms to make a larger atom. (B3) There is a decrease in the total mass of the atoms in a fusion reaction, so this process results in the release of large amounts of energy, according to Einstein's equation  $E = mc^2$ . (B5)

**nuclear membrane** The structure that separates the nucleus from the rest of a eukaryote cell. (B4)

**nuclear reaction\*** A process in which atoms, or more precisely their atomic nuclei, are not conserved; instead, one atomic nucleus is converted into different nuclei. (B6)

**nucleic acid** A biopolymer in which the monomers are nucleotides. There are two types of nucleic acid: DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). (B9)

**nucleons\*** The particles present in the nucleus of an atom. A nucleon may be either a proton or a neutron, and the total number of nucleons is equal to the mass number of the isotope in question. (B6)

**nucleosynthesis\*** The process by which an atomic nucleus of an element (other than hydrogen) is formed. There are believed to be three sites (or epochs) where (or when) nucleosynthesis occurs (or has occurred). Light nuclei, such as deuterium, helium and lithium, were formed in the early Universe when the Universe was between about 100 s and 1 000 s old. Nuclear fusion inside the cores of stars is responsible for the formation of more helium nuclei, and also for the formation of other nuclei up to those with a mass around that of iron. Supernovae explosions are responsible for the formation of more massive nuclei. (B11)

**nucleotide\*** A monomer of DNA (deoxyribonucleic acid) or RNA (ribonucleic acid), which consists of three covalently linked parts: a phosphate group, a sugar (deoxyribose or ribose) and a base. (B9)

**nucleus** (of an atom) See atomic nucleus.

**nucleus\*** (plural: nuclei) (of a cell) A component of a eukaryote cell surrounded by a nuclear membrane; the nucleus contains chromosomes, each chromosome consisting of DNA (the cell's genetic material) and protein molecules. (B4)

**nuclide** An atomic nucleus with a specified combination of neutrons and protons. (B7, A5.1)

**oblique plate motion** The motion of a lithospheric plate that is neither perpendicular to nor parallel to a plate boundary. (B3)

**observable Universe** That part of the Universe that it is theoretically possible to observe. See radius of the currently observable Universe. (B11)



**obsidian** A dark-coloured, smooth, volcanic glass, formed by very rapid cooling of a felsic magma. (B10)

**ocean trench\*** A long, linear trough in the ocean floor, typically three or more kilometres deeper than nearby ocean floor. (B3)

**octane number\*** A rating of the 'knock' characteristics of motor fuels. The octane number is equal to the numerical value of the percentage by volume of *iso*-octane,  $C_8H_{18}$ , in a mixture of *iso*-octane and heptane,  $C_7H_{16}$ , having the same knock characteristics as the fuel being tested. (B8)

**one gene — one polypeptide hypothesis** This states that the DNA in a gene has a precise linear sequence which codes for the linear sequence of amino acids in one polypeptide (protein). The relationship holds true for polypeptides that are produced in prokaryotes but not for those made in eukaryotes, in which they are the product of split genes. (B9)

**open cluster** A loose association of stars that were born from contracting gas in a galaxy, particularly in the arms of a spiral galaxy. (B3)

**open Universe\*** A model of the Universe in which the density of matter is not sufficient to halt the expansion. An open Universe is infinite in size at all times and will expand forever. In an open Universe, the actual density is less than the critical density. (B11)

**ophiolite\*** A fragment of oceanic lithosphere emplaced within a continent, typically as a result of plate collisions. Ophiolites comprise a set of particular rock types: basalt lava, a sheeted dyke complex, gabbro and peridotite (often altered to serpentinite). (B3)

**orbit\*** The path taken by one body moving around another body; for example, the path of a planet around the Sun. (B2) The path of any celestial body around another. (B3)

**orbital period\*** The time it takes one celestial body to complete one orbit around another. (B3)

**order** The level of taxonomic classification between class and family. For instance, the order Carnivora is part of the class Mammalia (mammals) and comprises eight families including Felidae (cats) and Canidae (dogs). (B4)

**order of magnitude\*** The approximate value of a numerical quantity expressed as the nearest power of ten. (B11)

**organelle\*** A membrane-bound structure within a cell. The most important organelles are the chloroplasts, mitochondria and the nucleus. (B9)

**organic carbon\*** Carbon in compounds formed by living organisms. Plants produce simple organic carbon compounds through photosynthesis. These are subsequently built up into more complex organic compounds by the plants themselves and by organisms that consume the plants. (B2)

**organic chemistry\*** The branch of chemistry that deals with the properties and reactions of carbon-based compounds. (B8)

**organic compounds** Compounds composed of molecules that are made up mainly of carbon and

hydrogen atoms, with other elements such as oxygen, nitrogen or the halogens. (B8)

**organic matter\*** Matter, either living or dead, containing organic carbon. (B2)

**origin** (of a graph) The point on a graph where both the horizontal scale and the vertical scale are zero. (B1)

**orogeny\*** The processes and/or sum of events during which a mountain belt is formed, e.g. the Caledonian Orogeny. An orogeny usually involves the convergence of lithospheric plates, causing folding, faulting, metamorphism and igneous activity. See also mountain-building. (B10)

**outer core** The liquid outer part of the Earth's core. (B3)

**outer electron configuration** The distribution of electrons within the outer sub-shells of an atom. For atoms of the typical elements, these outer sub-shells are *ns* and *np*, where *n* is the period number of the element in the Periodic Table, and the outer electron configuration is obtained by specifying the *ns* and *np* electron populations. For example, the outer electron configuration of the sulfur atom is  $3s^2 3p^4$ . (B8)

**ovule** A haploid female gamete produced in a plant through meiosis. (B4)

**ovum\*** (plural: ova) A haploid gamete produced by a female animal through meiosis. (B4)

**oxaloacetate** A 4C intermediate in the TCA cycle which reacts with acetyl (2C) in the form of acetyl CoA to form citrate (a 6C intermediate). (B9)

**oxidation\*** A chemical reaction that involves the addition of oxygen atoms to or the removal of hydrogen atoms from a particular compound. Oxidation is the opposite of reduction. (B8)

**oxidative phosphorylation\*** The process by which ATP is produced from ADP and P<sub>i</sub> in the presence of oxygen. The energy for ATP synthesis is provided by the oxidation of NAD<sub>2</sub>H via electron transport in Stage 4 of glucose oxidation. (B9)

**oxide\*** A chemical compound containing oxygen and other elements. Also a mineral containing metal atoms combined with oxygen, e.g. haematite,  $Fe_2O_3$  (an iron oxide). Silicates are so abundant and diverse that they are usually considered separately. (B10)

**ozone layer** A layer within the Earth's atmosphere, at an altitude of about 30 km, where ozone gas is prevalent. (B3)

**P wave\*** A type of seismic wave; the faster body wave. This is a compressional wave. (B3)

**P-wave shadow zone\*** The part of the Earth's surface where a P wave does not arrive. This shadow zone is caused by refraction of P waves at the boundary between the mantle and the core. It occurs where the epicentral angle is between  $105^\circ$  and  $143^\circ$ . (B3)

**pair creation\*** The spontaneous creation of a matter-antimatter pair of particles from energy, such as a photon of electromagnetic radiation. The opposite process is referred to as annihilation. The energy of the photon is converted into the mass of the matter and antimatter particles. For example, a photon of energy greater than about 1 MeV can spontaneously create an



**electron-positron pair**, each of which has a mass of  $511 \text{ keV}/c^2$ . (B11)

**palaeoclimate** The climate which prevailed in an area at some time in the geological past. Some climates are characterized by particular types of rock (such as coal or till), so the presence of such rock types can be used to reconstruct palaeoclimate. (B3)

**palaeolatitude** The latitude at which a rock or fossil was formed some time in the past. This can be deduced from the palaeomagnetism recorded in rocks. Other lines of evidence, such as sediment typical of a particular climate zone, can also be used to infer palaeolatitude. (B3)

**palaeomagnetism\*** The magnetism preserved in rocks at the time they were formed. The palaeomagnetism of a rock can indicate the latitude at which it formed. (B3)

**Palaeozoic\*** The oldest era of the Phanerozoic, consisting of the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian Periods. It lasted from 545 to 248 Ma ago. (B10)

**parallax** In an astronomical context, the phenomenon by which photographs of the same part of the sky, taken six months apart, reveal that nearby stars appear to move by tiny amounts with respect to more distant objects. (B11)

**parallax angle\*** ( $\psi$ ) Half the angular shift that is apparent in the positions of nearby stars when photographed six months apart. It is the basis of the definition of the astronomical distance unit known as the parsec. (B11)

**parasite\*** An organism that lives in or on another living organism, consuming parts of that organism. (B4, A7.1)

**parent nuclide** A radioactive nuclide that undergoes alpha-decay, beta-minus decay, beta-plus decay or electron capture. The products of the radioactive decay are referred to as daughter nuclides. (B7, A5.1)

**parental generation (P)** Parents (usually pure-breeding) which when crossed together produce the first filial generation ( $F_1$ ). (B9)

**parsec\*** (pc) An astronomical distance unit equal to about  $3 \times 10^{16} \text{ m}$ . A parsec is that distance at which a star would exhibit a parallax angle of one arc second. (B11)

**partial melting\*** The incomplete melting of a rock, during which the minerals with the lowest melting temperatures melt first, producing a liquid with a composition different from that of the original unmelted rock. An important cause of magmatic diversity. Compare fractional crystallization. (B10)

**particle model\*** A model that assumes that all matter is made from particles. These particles are very small, approximately  $10^{-10} \text{ m}$  across. The way these particles behave in a solid, liquid and gas explain the properties of these states of matter. (B2)

**particulate carbon\*** Particles containing carbon, either as organic carbon or as carbonate. (B2)

**parts per million (p.p.m.)\*** A way of defining proportions which assumes that the whole is made of a million parts. Thus the proportion of any component can be expressed as a fraction based on the number of millionths — the parts per million. For example,

121 p.p.m. is 121 parts out of a million parts which, expressed as a fraction, is  $\frac{121}{1000000}$ . (B2)

**pathogen** A disease-causing organism, including bacteria and viruses, and also parasites, such as tapeworms. (B9)

**peptide bond\*** The covalent bond or link formed by a condensation reaction between two adjacent amino acids in a protein (or polypeptide) chain and which is referred to as an amide group in chemistry. (B9)

**percentage\*** A way of expressing a fraction represented as hundredths. So twelve per cent, or 12%, is the same as twelve-hundredths, or  $\frac{12}{100}$ . To convert any fraction into a percentage you multiply it by 100%. Expressing values as percentages enables them to be easily compared. (B1)

**perennial** A plant which undergoes reproduction more than once in the course of its life history, e.g. an oak tree. Compare with annual and biennial. (B4)

**peridotite\*** A crystalline rock containing mainly the olive-green mineral olivine. Peridotite forms the Earth's mantle. (B3) When it partially melts it forms basaltic magma. (B10)

**period\*** (geological) An interval of geological time that is a subdivision of an era, e.g. the Jurassic Period in the Mesozoic Era. (B10)

**period\*** (of a wave) ( $T$ ) The interval of time it takes for a single complete cycle of a wave to pass a fixed point. Equal to one over the frequency of a wave,  $T = \frac{1}{f}$ . (B7)

**period\*** (Periodic Table) A series of chemical elements, commonly placed in a horizontal row in the Periodic Table. Across the row, atomic number increases in steps of one, and there is a variation in chemical properties that is repeated within other corresponding series of the table. (B6)

**Periodic Table\*** An arrangement of the chemical elements on paper that illustrates the nature of chemical periodicity. The arrangement is ordered with respect to atomic number. Elements that are similar can then be grouped together, often in columns; elements that are different are arranged in a way that matches certain regularities in their differences. (B6)

**petrochemicals** Chemicals that have been obtained from crude oil by distillation or chemical conversion. (B8)

**pH scale\*** A scale that provides a convenient measure of the acidity of an aqueous solution. If the hydrogen ion concentration of a solution is  $1 \times 10^{-n} \text{ mol litre}^{-1}$ , then the pH of the solution is  $n$ . The lower the pH, the more acid the solution. A pH of 7 corresponds to a neutral solution. (B8)

**Phanerozoic\*** The interval of geological time from the start of the Cambrian Period (545 Ma ago) to the present day. The Phanerozoic Eon is divided into three eras. Compare Cryptozoic. (B10)

**phenotype\*** The sum of all the characters that an organism possesses; or one particular character, e.g. the purple-grain phenotype of maize. The phenotype is determined by the interaction of the genotype and the environment. (B9)



**phosphate group** A negatively charged group containing one phosphorus atom covalently linked to four oxygen atoms. (B9)

**phospholipid\*** A water-insoluble compound composed of two long-chain fatty acid molecules and a negatively charged phosphate group. Phospholipids, together with proteins are the key components of biological membranes. (B9)

**phospholipid bilayer** Fluid structure consisting of two layers of phospholipid molecules arranged so that the hydrophilic phosphate groups are on the outside, and the hydrophobic fatty acid chains are on the inside away from surrounding water molecules. (B9)

**photoelectric effect\*** The phenomenon in which light and other electromagnetic radiation cause electrons to be ejected from the surfaces of certain metals. Quantified by Einstein's equation  $E_{k,max} = E_{ph} - E_0$  where  $E_{k,max}$  is the maximum kinetic energy of the electrons ejected,  $E_{ph}$  is the energy of the incident photons, and  $E_0$  is the minimum energy required to eject electrons from a particular metal. (B7)

**photoelectrons\*** The electrons ejected from a metal surface in the photoelectric effect. (B7)

**photometer** A device attached to a telescope that is used to measure the brightness of astronomical objects. (B11, A2.2)

**photon\*** A particle of light or other electromagnetic radiation. Monochromatic light consists of photons that each have exactly the same amount of energy, called a quantum of energy. (B7) The quantum of energy associated with the electromagnetic interaction. Photons have no mass or electric charge and do not experience the electromagnetic interaction. Compare this behaviour with gravitons and gluons, which also have no mass or electric charge, however gravitons experience the gravitational interaction, and gluons experience the strong interaction. (B11)

**photophosphorylation\*** Literally, light-driven phosphorylation. The synthesis of ATP from ADP and P<sub>i</sub>, using energy from sunlight as in photosynthesis. (B9)

**photosphere\*** The luminous surface of the Sun (or of other stars). (B3)

**photosynthesis\*** The production by green plants (including algae) and some bacteria of compounds containing organic carbon from carbon dioxide and water using the energy of sunlight. Oxygen is produced as a by-product. (B2)

**phylogeny** The evolutionary history of a group of organisms. (B9)

**phylum\*** (plural: phyla) The level of taxonomic classification between kingdom and class. For example, the phylum Chordata (mostly animals with backbones) is part of the kingdom Animalia (animals) and comprises several classes including Mammalia (mammals) and Aves (birds). (B4)

**physical weathering\*** The mechanical breakdown of rocks *in situ* at the Earth's surface into smaller fragments, by physical processes such as frost shattering, penetrating roots, thermal expansion and contraction. Contrast chemical weathering. (B10)

**phytoplankton** Plankton that produce compounds containing organic carbon by photosynthesis; they include algae and some bacteria. (B2)

**pi\*** ( $\pi$ ) A dimensionless number obtained by dividing the circumference of a circle by its diameter. It has a value of 3.141 592 654 (to 9 decimal places). (B11)

**P<sub>i</sub>** (inorganic phosphate) This negative ion is released when ATP is converted into ADP. Conversely, P<sub>i</sub> combines with ADP to form ATP. (B9)

**pico** A prefix to a unit, which means one-million-millionth, or  $10^{-12}$ ; for example, a picometre is  $10^{-12}$  metre (1 pm =  $10^{-12}$  m). (B8)

**pie chart** A graphical representation that shows relative amounts. It consists of a circular disc divided into segments by a set of lines from the centre — rather in the manner of cutting a circular pie. The area of the segment is proportional to the amount represented by that segment. For example, the relative amounts of the different atmospheric gases can be shown by a pie chart in which each segment represents the proportion of the atmosphere that consists of a different gas. (B2)

**pillow lava\*** Lava with a pillow-like shape in cross-section. Typically formed when basalt magma erupts onto the ocean floor. (B3)

**pion\*** A subatomic particle. An example of a meson. There are three types of pion:  $\pi^+$  consisting of an up quark and an antidown quark; ( $\pi^-$ ) consisting of a down quark and an antiup quark;  $\pi^0$  consisting of either an up quark and an antiup quark, or a down quark and an antidown quark. (B7)

**Planck constant\*** ( $h$ ) The fundamental constant relating to quantum physics. Expressed as  $h = 6.6 \times 10^{-34}$  J s or  $4.1 \times 10^{-15}$  eV Hz<sup>-1</sup>. Defined by the equation  $E_{ph} = hf$  linking energy of photons with frequency. (B7)

**Planck energy** ( $E_{pl}$ ) A natural energy scale of the Universe, defined in terms of other physical constants. It has a value of about  $10^{19}$  GeV. The energy at which superunification of the four fundamental interactions is believed to occur. (B11)

**Planck length** A natural length scale of the Universe, defined in terms of other physical constants. It has a value of about  $10^{-35}$  m. The distance that light could travel during the Planck time. (B11)

**Planck mass** ( $m_{pl}$ ) A natural mass scale of the Universe, defined in terms of other physical constants. It has a value of about  $2 \times 10^{-8}$  kg. The mass corresponding to the Planck energy such that  $E_{pl} = m_{pl}c^2$ . (B11)

**Planck time** A natural time scale of the Universe, defined in terms of other physical constants. It has a value of about  $5 \times 10^{-44}$  s. When the Universe was this old, it is believed that the superunification of the four fundamental interactions broke down. (B11)

**planetary albedo\*** The average global rate at which solar radiation is scattered and reflected back to space by a planet (such as the Earth), divided by the average global rate at which solar radiation is intercepted by the



planet. It can be expressed as a fraction, decimal or percentage. See also reflection, scattering. (B2)

**planets** Natural bodies in orbit around the Sun that shine by reflecting sunlight. A planet's interior is always too cool for nuclear fusion to occur. (B3)

**plankton\*** Animals and plants of the sea or fresh water, which float or drift almost passively. Most plankton are microscopic but some, such as some jellyfish, can be quite large. (B2)

**Plantae\*** The formal name for the plant kingdom, one of four kingdoms within the domain Eukarya. (B4)

**plastic deformation\*** (of rocks) A form of deformation, usually at high temperatures and pressures, in which rocks respond to earth movements by stretching to become thinner when under tension, and by bulging and bending (folding) rather than fracturing when under compression. (B10)

**plate\*** See lithospheric plate.

**plate reconstruction** A representation of the position of each lithospheric plate at a particular time in the past. (B3)

**plate tectonics** The movement of a lithospheric plate around the Earth and the processes which result from that movement. Plates move as 'caps' on the spherical surface of the Earth, and interact at their edges. (B3)

**pluton\*** A large body of igneous rock that has crystallized deep beneath the Earth's surface. Some are huge bodies (intrusions) many hundreds of cubic kilometres in volume. Such intrusive rocks are coarse-grained, having cooled slowly to form large crystals. (B10)

**polarity reversal\*** A change in the polarity of the Earth's magnetism, either from reversed polarity to normal polarity, or normal to reversed. (B3)

**pole** (of rotation) An imaginary point on the surface of a rotating object, where the axis of rotation passes through the surface. (B2)

**pole** (of spindle or cell) The two ends of a cell from which the spindle fibres emanate and to which the chromosomes separate during anaphase and collect at telophase of nuclear division. (B9, A8.4)

**pollen diagram\*** A diagram showing how the proportion of pollen grains from different plant types varies from layer to layer in sediment. A pollen diagram is arranged with sample depth increasing downwards on the vertical axis, and this corresponds to increasing age of the samples. A pollen diagram reveals how the types of plant growing in a region may have changed over a period of time. (B2)

**pollen grain** A structure similar to a spore (but with very limited growth capabilities) that brings the haploid male gamete produced by a plant close to a suitable female gamete. (B4)

**polyatomic ion\*** An ion formed by the loss or gain of electrons from a molecule or chemical group composed of two or more atoms. (B6)

**polymer\*** A large molecule formed by the linking together of many smaller molecules known as monomers. (B8)

**polymerization\*** The process by which monomers are joined together to give a polymer. (B8)

**polymorph\*** (minerals) One of two or more substances that have the same chemical composition, but different crystal structures. (B10)

**polymorphic\*** A species is described as polymorphic if it consists of a number of 'types' with distinctive morphology. (B4)

**polymorphism\*** The existence within a species of two or more distinct forms of a character, gene or DNA sequence in a population, for example, the pale and dark forms of the peppered moth, the ABO blood groups, and the normal and mutant forms (alleles) of the cystic fibrosis gene. (B9)

**polynucleotide** A polymer of nucleotides, such as DNA or RNA molecules. The phosphate group of one nucleotide forms a covalent bond to the sugar (deoxyribose in DNA, ribose in RNA) of the adjacent nucleotide in the polynucleotide chain. (B9)

**polypeptide\*** A sequence of amino acids linked together by peptide bonds. The term is used interchangeably with protein. (B9)

**polyploidy\*** The multiplication of whole sets of chromosomes (each set being the haploid number,  $n$ ). For example a tetraploid has  $4n$  chromosomes and a hexaploid has  $6n$  chromosomes instead of the usual diploid number of  $2n$ . (B9)

**polysaccharide\*** A biopolymer chain of covalently-linked monosaccharides (sugars); the chain may be branched as in glycogen, or unbranched as in cellulose. (B9)

**polysome\*** The name for the structure of a group of ribosomes and partially made polypeptides attached to a single molecule of mRNA during the process of translation. (B9)

**population\*** A group of organisms belonging to the same species which live in a defined place. (B4)

**population density\*** A measure of the number of people (or organisms) living within a certain area. In a city there are a large number of people living in an area of  $1 \text{ km}^2$ , so the population density is high. In a desert the population density is low. (B1) More generally, population density is the average number of organisms of the same species present in a specified area or volume. (B4)

**population size\*** The total number of organisms that are members of a defined population. (B4)

**porphyritic** The texture of an igneous rock in which large, early-formed crystals are set in a groundmass of finer-grained crystals. (B10)

**positive feedback\*** This occurs when an increase (decrease) in one quantity causes changes to other quantities that eventually lead to the original quantity being increased (decreased) even further. See also negative feedback. (B2)

**positron\*** ( $e^+$ ) A fundamental particle, the antimatter counterpart to the electron (an antilepton). It has positive electric charge, but the same mass as the electron. It is produced in beta-plus decay processes. (B7)

**potential energy\*** Energy that is stored, and which depends on the position of an object and not on its motion. So-called because the object has the potential to do work when its position changes. Gravitational energy and strain energy are both forms of potential energy, and



so is electrical energy. One component of the internal energy of a substance is associated with the potential energy of the atoms and molecules within the substance. (B5)

**power\*** The rate at which energy is transferred from one object to another, i.e. the amount of energy transferred in one unit of time. In SI units, the unit of power is  $\text{J s}^{-1}$ , more commonly known as the watt, W. (B2) Electrical power is the rate at which electrical energy is converted into other forms of energy, and is related to the electric current  $I$  and the voltage difference  $\Delta V$  by the equation  $P = I\Delta V$ . (B5)

**power\*** (in mathematics) A superscript after a number or unit. A positive power indicates how many times that number or unit must be multiplied by itself; for example,  $2^3 = 2 \times 2 \times 2$ , where the power is 3. A negative power indicates how many times you must divide by the number or unit; for example,  $\text{m}^{-2} = \frac{1}{\text{m} \times \text{m}}$  where the power is -2. (B1)

**powers of ten\*** A notation for representing a number as a larger or a smaller number multiplied by a power of ten. For example, in powers of ten notation, 1 234 can be written as  $1.234 \times 10^3$  or  $12.34 \times 10^2$  or  $0.1234 \times 10^4$  or  $123\,400 \times 10^{-2}$ . When the decimal number is between 1 and 10, for example,  $1.234 \times 10^3$ , then this is also known as scientific notation. (B1)

**p-p chain** See proton-proton chain.

**Precambrian\*** An informal but much-used term for the Cryptozoic Eon, an immensely long interval from the origin of the Earth, 4 600 Ma ago, to the start of the Cambrian Period, 545 Ma ago. (B10)

**precipitate\*** A solid that appears in the form of fine particles in what was previously a clear solution because of a chemical reaction. (B6)

**precipitation\*** A collective term that includes all the forms in which water from the air falls on the Earth's surface (as rain, snow, sleet or hail, and also as frost and dew). (B1)

**precision\*** A measurement has a high precision if the random uncertainty associated with it is small. A series of high precision measurements will show only a small scatter; lower precision measurements will show a larger scatter in the measured values. (B2)

**predator** An animal that catches and consumes, either in whole or in part, other animals (its prey). (B4, A7.1)

**pre-reproductive generation mortality\*** The overall mortality of individuals, who have not reached reproductive maturity, that occurs in a single generation of an organism. Represented by the symbol  $k_{\text{total}}$ . (B9, A1.1)

**prehensile** Able to seize, grasp or pluck an object, especially by wrapping round it. (B4, A9.1)

**preservation potential\*** The chance that an organism, or part of an organism, has of getting preserved in the fossil record. Various factors affect preservation potential, e.g. whether the organism's body has any durable parts, where it lives and whether it becomes buried in sediment. (B10)

**pressure\*** Each time a particle of a gas collides with the wall of its container it exerts a force on the wall for a

short time. There are so many particles in a gas that the collisions with the walls lead to a steady force. Pressure is the magnitude of the force on a surface divided by the area of the surface. Pressure is measured in bars. (B2) The definition of pressure as force/area also applies to solids and liquids.

**prey** An animal which is caught and consumed, either in whole or in part, by another animal (a predator). (B4, A7.1)

**primary RNA product\*** mRNA complementary to the DNA of a split gene, i.e. the product of transcription of both exons and introns. (B9)

**primary structure\*** (biopolymer) The sequence of specific amino acids in a protein, or of sugars in a polysaccharide, or of nucleotides in a nucleic acid. (B9)

**principal quantum number\*** The number  $n$  used to characterize the energy levels in a hydrogen atom. One of four quantum numbers used to describe the quantum states occupied by electrons in atoms. (B7)

**principle of faunal succession\*** The principle that strata contain particular assemblages of fossils in a definite succession, with each stage in this succession representing a particular span of geological time. (B10)

**principle of superposition\*** The principle that, because younger sediments are deposited on older sediments, an individual rock layer is younger than the one beneath it and older than the one above it. Unless the strata have been disturbed or overturned, the oldest layer lies at the bottom. (B10)

**principle of uniformitarianism\*** The principle that processes operating in the distant past were the same as those that are observed, or can be inferred to operate, at the present day. Uniformitarianism demands that the interpretation of rocks should be in terms of the known laws of natural science. Contrast with catastrophism. (B10)

**probability\*** The quantitative value for the chance or likelihood that a given outcome will occur. Probabilities have values between zero and one. A probability of one indicates a certainty. (B7)

**producer\*** An organism that makes its own carbon-based material starting with carbon dioxide. A producer is also known as an autotroph. Almost all plants are producers; they convert carbon dioxide into carbon-based material by photosynthesis. Compare with consumer and heterotroph. (B4, A7.1)

**product\*** (in chemistry) A substance that is produced during a chemical reaction. See also reactant. (B2)

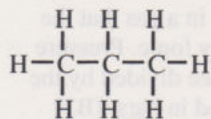
**product** (in mathematics) The operation by which one quantity is multiplied by another quantity. (B11)

**progeny cells\*** The cells produced by cell division of a previously existing parent cell. (B4)

**prokaryote\*** (adjective: prokaryotic) An organism comprising a single cell (with a few exceptions) in which the DNA is not contained within a nucleus. Prokaryotes are members of either the domain Archaea or the domain Bacteria. Compare with eukaryote. (B4)

**propane** An alkane with the molecular formula  $\text{C}_3\text{H}_8$ , the abbreviated structural formula  $\text{CH}_3\text{—CH}_2\text{—CH}_3$  and the structural formula





(B8)

**prophase\*** The phase of mitosis in which chromosomes can first be seen in the cytoplasm of the cell, the nuclear membrane which normally surrounds the nucleus having disappeared. During prophase each chromosome consists of a chromatid pair attached at a centromere. (B4)

**proportion** The size, number or amount of one object or group as compared to the size, number or amount of another. A proportion can be expressed as a fraction, ratio or percentage. (B1)

**proportional to\*** Two quantities are said to be proportional to each other if, when the value of one is multiplied (or divided) by a certain amount, the value of the other also becomes multiplied (or divided) by the same amount. For example, the cost of petrol is proportional to the volume of petrol bought, so the cost of buying 50 litres of petrol is twice the cost of buying 25 litres of petrol which is five times the cost of buying 5 litres. The volume of petrol divided by its cost has the same, constant, value no matter how much petrol is involved. (B2) When two quantities  $x$  and  $y$  are proportional to each other, this can be written as  $y \propto x$ . On a graph of  $y$  against  $x$ , they would plot as a straight line passing through the origin with gradient equal to  $y/x$ . (B3) The proportionality  $y \propto x$  can be converted into the equation  $y = kx$  by introducing a constant of proportionality  $k$ . (B5)

**protein\*** A very large, naturally occurring polyamide formed from a selection of the 20 or so naturally occurring amino acids. See also polypeptide. (B8)

**Protoctista\*** The formal name for the kingdom of the organisms known informally as prototists; one of four kingdoms within the domain Eukarya. (B4)

**proton\*** The nucleus of the hydrogen atom and one of two constituents of all other nuclei; the particle has a mass very close to one on the international scale of relative atomic masses. It is positively charged and the value of its electric charge is  $e = 1.6 \times 10^{-19} \text{ C}$ . (B6) A proton is a baryon, with the quark composition (uud). It has a mass of about  $1 \text{ GeV}/c^2$ . (B7)

**proton pump\*** A membrane-bound protein with a central channel for protons ( $\text{H}^+$  ions). It uses the energy of electron transport to pump protons through the central channel, from one side of the membrane where proton concentration is low, to the other side where proton concentration is high, i.e. against a proton concentration gradient. Three of the five carriers of the ETC in the inner mitochondrial membrane are proton pumps and similarly some of the carriers of the ETC in the inner chloroplast membrane are also proton pumps. (B9)

**proton-proton chain** The sequence of nuclear fusion reactions by which hydrogen nuclei are converted into helium atomic nuclei in the core of the Sun and other stars. (B11)

**protractor** A device for measuring the size of an angle, and for helping to draw angles. (B2)

**pumice** A rough-textured, pale-coloured extrusive igneous rock, formed by solidification of magma froth; a volcanic glass, full of gas bubbles. (B10)

**pupa\*** (plural: pupae) Stage in the life cycle of many insects between larva and adult; during this stage the organism undergoes a transformation from larva to adult, protected by a tough pupal case. (B4, A7.1)

**pure-breeding\*** A variety of organism that possesses a particular character and which, when interbred over a number of successive generations, produces offspring all of which possess that character. (B9)

**pyramid of energy\*** Diagrammatic representation of a food chain, in which the energy at each trophic level is represented by the size of a flattened cube. The cubes are stacked in the same order as the trophic levels in the food chain, resulting in a pyramid. (B4, A7.1)

**pyramid of numbers** Diagrammatic representation of a food chain, in which the number of organisms at each trophic level is represented by the size of a flattened cube. The cubes are stacked in the same order as the trophic levels in the food chain, usually resulting in a pyramid. (B4, A7.1)

**pyroclast\*** A volcanic rock formed during a pyroclastic eruption. Pyroclasts, such as volcanic ash, are formed when magma or existing rock is explosively erupted and fragments are flung into the air. (B3)

**pyroclastic eruption\*** A volcanic eruption in which fragments of magma, volcanic gas and pre-existing rocks are explosively ejected from a volcano. This type of eruption is usually caused by the sudden expansion and escape of dissolved gases from the magma during eruption of a volcano. Also known as an explosive eruption. This style of eruption contrasts with that of an effusive eruption. (B3)

**pyruvate\*** The three-carbon compound formed from glucose in the last step of glycolysis in the cytosol. In aerobic respiration, pyruvate passes to the mitochondria, where it takes part in the link reaction. In anaerobic respiration, it is reduced in the cytosol to lactate. (B9)

**QCD** See quantum chromodynamics.

**QED** See quantum electrodynamics.

**qualitative** (information) Information or data that do not involve numbers, for example, colour, smell or taste, are said to be qualitative. See also quantitative. (B1)

**quanta** See quantum.

**quantitative** (information) Measurements or data with numbers and units attached to them, for example the number of centimetres of rain per year, are said to be quantitative. See also qualitative. (B1)

**quantized** Having only certain (allowed) values. (B7)

**quantum\*** (plural: quanta) The amount of energy carried by a single photon of light or other electromagnetic radiation. (B7)

**quantum** A particle that mediates, or is transferred in, one of the four fundamental interactions or one of the unified interactions, i.e. photons, gluons, W and Z bosons, gravitons, Higgs bosons, X bosons.

**quantum chromodynamics\*** (QCD) The theory that describes the strong interaction. It explains these interactions as arising due to the exchange of gluons



between particles that possess colour charge. For comparison *see* quantum electrodynamics. (B11)

**quantum electrodynamics\*** (QED) The theory that describes the electromagnetic interaction. It supersedes Maxwell's laws of electromagnetism in situations where the size scales are very small and the energy scales very large. It incorporates ideas from both quantum physics and the theory of special relativity and explains the electromagnetic interaction as arising due to the exchange of photons between particles that possess electric charge. For comparison *see* quantum chromodynamics. (B11)

**quantum gravity\*** A theory which would unify quantum physics with the gravitational interaction. No such theory yet exists, but any such theory would predict the existence of quanta called gravitons. (B11)

**quantum numbers\*** Whole numbers used to describe the quantum states occupied by electrons in atoms. The first two quantum numbers are specified by the letters *n* and *l*. (B7)

**quantum physics\*** The theory and study of systems of particles which exhibit quantized energy levels, and indeterminate positions and speeds. (B7)

**quantum state\*** A description of the properties of an atom or other quantum system. Specified in terms of quantum numbers. In general, more than one quantum state will be associated with each of the energy levels of an atom. (Sometimes shortened to state.) (B7)

**quantum system** Used to refer to any system in which energy levels exist, and which therefore emits or absorbs quanta of light or other electromagnetic radiation, and/or in which the constituent particles have indeterminate positions and speeds. (B7)

**quark\*** A fundamental particle, the matter counterpart of an antiquark. There are six types (flavours) of quark: up quark (u), down quark (d), charm quark (c), strange quark (s), top quark (t), and bottom quark (b). Quarks are found in both baryons and mesons but never in isolation. (B7)

**quartz** A common mineral composed of two kinds of chemical element, silicon and oxygen. It occurs in many types of sedimentary rock, igneous rock and metamorphic rock: for example, it is found as grains cemented together in sandstone, and is one of the types of crystal in granite. (B3)

**r\*** *See* intrinsic rate of natural increase.

**race** A population from a particular species that shows slight differences from other races belonging to the same species. (B9)

**radiation** Something that spreads out from a source. *See also* electromagnetic radiation. (B2)

**radioactive decay\*** The spontaneous change of an atomic nucleus accompanied by the emission of alpha-particles, beta-particles or gamma-rays. (B6)

**radioactivity** The emission of particles and  $\gamma$ -radiation from atomic nuclei during radioactive decay. It was first detected by accident when the emissions were found to affect a photographic film. (B6)

**radiometric dating\*** The method of determining the absolute age of a rock using the decay of naturally occurring radioactive isotopes. Age determination

involves the measurement of the amounts of the radioactive parent and stable daughter isotopes in the rock, and the determination of the D/P value. All radiometric dates have an associated uncertainty. (B10)

**radius\*** (plural: radii) The distance (in a straight line) from the centre of a circle to its perimeter, or from the centre of a disc to its edge, or from the centre of a sphere to its surface. Also, the straight line itself. (B3)

**radius of the currently observable Universe** The distance out to which it is theoretically possible to see. Given by  $3ct$ , where *t* is the age of the Universe (or strictly speaking, the time since matter and radiation last interacted in the Universe, about 300 000 years after the Big Bang). It is roughly equal to the horizon distance in the non-inflationary model for the expansion of the Universe, but significantly less than the horizon distance in the inflationary model for the expansion of the Universe. (B11)

**random uncertainty** A series of measured values of a quantity will generally be scattered randomly about a mean value. The larger the random uncertainty associated with the measurements, the larger will be the scatter. *See also* precision. (B2)

**range** The geographical area over which a species, population or individual organism can be found. (B9)

**raptor** Common name used for predator birds (e.g. sparrowhawks), the prey of which are mostly land-based vertebrates (i.e. animals with backbones). (B4, A7.1)

**rate** The change in a quantity divided by the time taken for that change. It is thus the change in one unit of time. For example, speed is the rate at which distance is traversed: it is the distance travelled in a certain time divided by the time taken. (B2)

**rate of reaction\*** The rate at which the concentration of a product increases or the concentration of a reactant decreases with time. (B8)

**rate of sea-floor spreading** *See* sea-floor spreading rate.

**ratio\*** The relationship between the sizes of two similar quantities. For example, if there are three men and eight women in a group, then the ratio of men to women is 3 to 8, and this ratio can be written as 3 : 8. Ratios do not have units attached to them. (B1)

**Rayleigh wave\*** A type of seismic wave; the slower surface wave. This wave is similar to waves on the surface of water, and it moves the ground surface horizontally and vertically. (B3)

**reactant\*** A substance that takes part in a chemical reaction and whose constituent atoms appear in the product(s) of the reaction. (B2)

**reaction** *See* chemical reaction.

**receptor\*** A protein molecule in the cell membrane that responds to chemical 'messengers' that are usually produced elsewhere in the organism. The protein molecule is folded in such a way as to form a cavity into which only molecules with the correct functional groups and geometry will fit. (B8)

**recessive\*** Term describing the character that is not manifest in a heterozygote; the phenotype of the



genotype carrying the recessive allele. (The character that *does* appear is referred to as dominant.) (B9)

**recombination\*** The process that generates new combinations of genes and alleles at meiosis, either by crossing over of homologous pairs of chromosomes or independent assortment of chromosomes. In general, it refers to a process that generates new gene or chromosomal combinations not found in that cell or organism and thus also can include the process of fertilization. (B9)

**recombination** (of an electron and an ion) *See* free-bound emission.

**Red Queen effect\*** This effect means that organisms have to change just in order to survive because their physical environment and/or their interaction with other species are constantly changing. In *Alice in Wonderland* the Red Queen was famous for stating that one had to keep running in order to stay in the same place. Coevolution is an example since there is constant change in interacting species. (B9)

**red-shift\*** ( $z$ ) The shift in the spectrum of a source of electromagnetic radiation that is receding from the observer. Quantified by the equation,  $z = \frac{\Delta\lambda}{\lambda_0}$ , where  $\Delta\lambda$

is the shift in wavelength of a particular feature in the spectrum and  $\lambda_0$  is the original (or rest) wavelength of the same feature. A red-shift corresponds to a lengthening of the emitted wavelength. All distant galaxies (beyond the Local Group) exhibit red-shifts, none exhibit blue-shifts. This is evidence that the Universe is expanding. (B11)

**reduction\*** A chemical reaction that involves the addition of hydrogen atoms to or the removal of oxygen atoms from a particular compound. Reduction is the opposite of oxidation. (B8)

**reflection\*** (of radiation) An interaction between radiation and matter in which the radiation is scattered from a surface, rather than penetrating the surface. *See* also scattering. (B2)

**refraction\*** The change in direction of a seismic wave (or any other type of wave) due to the wave travelling from one region to another in which it has a different speed (e.g. across a seismic discontinuity). (B3)

**regional metamorphism\*** The metamorphism of vast volumes of rock, accompanied by deformation that occurs mainly during mountain-building at subduction zones and zones of continental collision. Regionally metamorphosed rocks are characterized by minerals that have grown in alignment as a result of deformation pressures. Contrast with contact metamorphism. (B10)

**regulating mortality factor\*** A  $k$ -value that varies in the opposite way to the pre-reproductive generation mortality factor  $k_{\text{total}}$  over a period of years. Regulating mortality factors are density dependent. (B9, A1.1)

**relative age\*** The age of one geological material or event compared with the age of another, stated simply in terms of whether it is older or younger. Compare with absolute age. (B10)

**relative atomic mass\*** A set of numbers, one for each chemical element, the ratio between the numbers for any two elements being equal to the ratio between the average masses of their atoms. The scale of numbers is fixed by assigning a value to one particular type of atom.

Until recently, this was done by assigning the value 16 to an oxygen atom. It is now done by assigning the value 12 to an atom of the carbon isotope  $^{12}\text{C}$ . When quoted to four significant figures, the two sets of relative atomic masses given by these two scales are identical. (B6)

**relative molecular mass\*** For any molecule, the sum of the relative atomic masses of each of the atoms contained within it. (B6)

**repeat sequences\*** Sequences of DNA, repeated or copied a large number of times, in eukaryote genomes, and with no known function. (B9)

**replication\*** A phase of the cell cycle between growth I and growth II during which the DNA molecules within the nucleus are copied. (B4)

**reproduction\*** The production of offspring by means of either asexual reproduction or sexual reproduction; one of the three attributes of life. (B4)

**reproductive isolation\*** Under normal circumstances, sexual reproduction occurs only between members of the same species, i.e. there is usually reproductive isolation between species. Reproductive isolation is therefore often used as a defining characteristic of species that reproduce sexually. However, since some interbreeding between species may occur in certain circumstances, reproductive isolation is a relative, not absolute, term. (B4) A situation where gene flow, between two populations or two species, does not take place, or at least is reduced to a very low level. (B9)

**reservoir\*** In a global cycle (e.g. water or carbon), reservoirs provide a means of classifying cycled material by type of location, irrespective of its real geographical location. For example reservoirs in the water cycle include the atmosphere, the oceans, ice and snow, etc. (B2)

**residence time\*** The average length of time that a molecule remains in a particular reservoir. (B2)

**respiration\*** The sum of every chemical reaction by which an organism breaks down simple organic carbon compounds (i.e. in food) to release energy. In most organisms respiration is accompanied by consumption of oxygen and production of carbon dioxide and water. (B2) In respiration the energy stored in organic compounds is released in a series of very small, highly-controlled steps, as part of the process of metabolism. (B4)

**rest wavelength** The wavelength of a spectral line that is observed when the source of the spectrum is not moving (i.e. is at rest) with respect to an observer. (B11)

**reversed polarity\*** When the Earth's magnetism was such that a compass needle would have pointed towards the South Pole, the Earth's magnetism is said to have had reversed polarity. Contrast normal polarity. (B3)

**rhyolite\*** A fine-grained felsic igneous rock. The extrusive equivalent of granite. (B10)

**ribonucleic acid\*** *See* RNA.

**ribose** A sugar molecule, containing five carbon atoms, that is part of the structure of nucleotides of RNA. (B9)

**ribosomal RNA\*** *See* rRNA.

**ribosomes\*** Small, roughly spherical objects that are present in the cytosol of prokaryotes and are attached to the surface of rough endoplasmic reticulum in



eukaryotes. The structures on which proteins are synthesized during translation. (B9)

**Richter scale\*** The scale of earthquake magnitude. An increase of one unit on the Richter scale means a tenfold increase in ground motion and about a 40 times increase in the seismic energy released. (B3)

**ridge-slide force\*** The force acting on a lithospheric plate due to oceanic lithosphere sliding off the elevated asthenosphere at a mid-ocean ridge. (B3)

**right angle\*** The angle between two directions that are perpendicular, i.e. at 90° to each other. (B2)

**RNA\*** A biopolymer in which the monomer is a composite molecule consisting of a phosphate group joined to a ribose sugar, which in turn is joined to one of four different bases — adenine, cytosine, guanine and uracil. Each RNA molecule consists of one polynucleotide strand. RNA molecules are involved in the process of protein synthesis in the cell (see mRNA, rRNA and tRNA). (B9)

**RNA polymerase** An enzyme that binds to the template strand of DNA during transcription and adds nucleotides of RNA according to the rules of base-pairing. (B9)

**RNA processing** The changes that occur to the primary RNA product before it becomes mature mRNA which is transported to the cytosol. Processing involves RNA splicing. (B9)

**RNA splicing\*** The reactions that occur to the primary RNA product following transcription: non-coding sequences, or introns, are removed and coding regions, or exons, are joined together to produce mature mRNA. (B9)

**rock\*** A naturally occurring assemblage of mineral grains. Rocks can be classified as sedimentary rock, metamorphic rock or igneous rock, depending on their mode of formation. (B3)

**rock cycle\*** The cycle in which rock materials (of any type) are continuously made and destroyed. (B3)

**rocky materials\*** A term used in Solar System studies for the sorts of materials that make up rock (and this includes metals, notably iron). (B3)

**rotation axis** See axis of rotation.

**rough endoplasmic reticulum\*** Membrane material organized into sack-like or sheet-like structures with a granular appearance due to small, roughly spherical objects attached to its surface. These are the ribosomes — the structures on which proteins are synthesized. (B9)

**rounding\*** Approximating a number by reducing the number of digits (usually to the right of the decimal point). Rounding follows a convention: if the last digit to remain is followed by a digit between 0 and 4 then it is left unchanged, but if the last digit to remain is followed by a digit between 5 and 9 then it is increased by one. (B1)

**rRNA\*** The RNA that together with proteins make up the structures called ribosomes which are the sites of synthesis of polypeptides by the process of translation. (B9)

**ruminant** A mammal that 'chews the cud', i.e. regurgitates and rechews its food. (B4, A9.1)

**runaway greenhouse effect\*** The situation in which an increase in the GMST of a planet causes, for example, the amount of greenhouse gases in the atmosphere to increase, which in turn causes the GMST to increase even further, and so on. It is an example of positive feedback. See also greenhouse effect. (B2)

**Rutherford model of the atom\*** A model of the structure of the atom; the atom is supposed to consist of a tiny, massive, positively charged core or nucleus, around which negatively charged electrons move in orbits. (B6)

**S wave\*** A type of seismic wave; the slower body wave. This is a transverse wave in which the rock moves at a right angle to the direction of wave motion. (B3)

**S-wave shadow zone\*** The part of the Earth's surface where an S wave does not arrive: caused by the liquid outer core, through which S waves cannot pass. It occurs where the epicentral angle is between 105° and 180°. (B3)

**salt\*** A type of substance that is formed when the hydrogen atoms of an acid are replaced, usually by the atoms of a metallic element, but sometimes by chemical groups such as ammonium, NH<sub>4</sub>. Salts or their solutions are formed in neutralization reactions between an acid and a base. (B6)

**sand\*** Granular sediment (grains >0.6 mm and <2 mm diameter), often composed of quartz grains, which feels gritty when rubbed between fingers. (B10)

**sandstone\*** A sedimentary rock made of sand (often quartz) grains laid down originally as loose sediment that have subsequently been buried, and undergone compaction and cementation. (B3, B10)

**saturated\*** (solution) This is a solution (usually of a solid solute in a liquid solvent) in which, in the presence of undissolved solute, no more solute will dissolve at the prevailing temperature and pressure. (B8)

**saturated compound\*** A term used to describe an organic compound with molecules in which all the atoms are connected by single bonds. In particular, each carbon atom is joined to four other atoms. (B8)

**saturation\*** The condition in which as much of a substance as possible is held within another substance, usually a liquid. For example, when the maximum amount of a salt (or gas) is dissolved in water, the salt (or gas) level is at saturation, and the solution is said to be saturated. (B1)

**scale** A set of divisions used for measurements, as on a ruler. Scales are used on the axes of a graph to allow data to be plotted at points corresponding to specific values. For example, each centimetre of the scale on the axis may represent one year, or it may represent 10 °C. (B1)

**scale bar** A line on a diagram that indicates the size of the object illustrated. For example, a one centimetre line on a diagram may represent a kilometre, showing that the object has been reduced in size, or a millimetre, in which case the object has been increased in size. (B1)

**scale model\*** A model that has all of its dimensions in a constant ratio to the dimensions of the real object, and might be made of different materials. (B2)



**scattering\*** (of radiation) An interaction between radiation and matter characterized by changes in the direction in which the radiation is travelling. (B2)

**schist\*** A coarse-grained metamorphic rock with an appearance dominated by highly reflective, aligned flakes of platy minerals, such as mica (B3), that produce a wavy foliation. Schist is formed at medium grades of regional metamorphism. (B10)

**Schrödinger model of the atom\*** A fully quantum model of the atom. It describes the quantized energy levels of atoms, and the indeterminate positions and speeds of the electrons in atoms. (B7)

**scientific label** Each properly described species has a binomial (two-word) scientific label which is used internationally as an aid to scientific communication; for example, the scientific label of humans is *Homo sapiens* (which can be abbreviated to *H. sapiens* provided there is no ambiguity). The first part of a scientific label is the name of the genus to which the species belongs, while the second part is unique to each species within that genus. Conventionally, scientific labels are italicized in print and underlined when handwritten. (B4)

**scientific method\*** The way in which advances in our knowledge and understanding of science are often made. Scientists produce a hypothesis to explain certain facts or observations. They test this hypothesis by making further observations or measurements. These results might confirm the hypothesis, or might lead scientists to modify the hypothesis, or to replace the hypothesis by a completely new hypothesis. (B1)

**scientific model** A scientific representation of the real world, in which simplifications are made to aid understanding by focusing on some particular aspects of reality. A scale model is one particular type of scientific model, but there are many others. (B2)

**scientific notation\*** A notation that represents any number by expressing it as a number between 1 and 10 multiplied by a power of ten. Thus  $1.30 \times 10^3$  is in scientific notation (because 1.3 is between 1 and 10), but  $0.130 \times 10^4$  and  $13.0 \times 10^2$  are not. See also powers of ten. (B1)

**scientific theory\*** A well-established explanation that is consistent with a wide range of observations and has been tested where possible by experiments. (B1) A theory is often a set of ideas or principles which apply equally in a number of different situations and can usually be supported by a number of lines of evidence. Contrast hypothesis. (B3)

**screening\*** The process by which the effective charge of an atomic nucleus is reduced by the presence of electrons between the nucleus and some more distant point. (B7)

**sea-floor spreading\*** The process by which each lithospheric plate on either side of a divergent plate boundary (mid-ocean ridge) grows. Igneous rock is added to each plate on either side of the ridge as they spread apart, to form new oceanic lithosphere. (B3)

**sea-floor spreading rate\*** The speed at which a lithospheric plate on one side of a divergent plate boundary moves apart from the plate on the other side, usually reported in  $\text{mm y}^{-1}$ . The full spreading rate gives the speed of separation of the two plates; the half

spreading rate gives the speed at which one plate moves away from the plate boundary. (B3)

**second\*** In SI units, the unit of time, abbreviated to s. (B1)

**second filial generation\*** ( $F_2$ ) The second generation of offspring produced when members of the first filial generation ( $F_1$ ) are crossed together. (B9)

**sediment\*** Material derived from pre-existing rock, from biological sources, or formed by chemical processes, that is deposited at or near the Earth's surface. (B2)

**sedimentary basin** An area of lowland or ocean floor where thick sequences of sediment accumulate. (B10)

**sedimentary rock\*** A rock formed from sediment laid down at the Earth's surface that has subsequently undergone lithification by processes such as compaction and cementation. Sedimentary rocks usually have a fragmental texture, with individual grains cemented together. Some other sedimentary rocks are formed by biological processes (for example coral reefs). (B3)

**sedimentation** The process by which any sediment is formed or laid down, for example, in river deltas or in the ocean. (B2)

**segregation\*** The separation of homologous chromosomes, or the separation of the two copies of a gene, at meiosis. (B9)

**seismic discontinuity\*** A surface within the Earth at which there is a significant change in seismic wave speed. (B3)

**seismic wave\*** A wave in the Earth, generated by an earthquake (or an explosion). (B3)

**seismic zone\*** An area of the Earth where earthquake activity occurs. (B3)

**seismogram\*** A paper record of ground motion due to a seismic wave recorded by a seismometer. (B3)

**seismometer** An instrument that measures and records motion of the ground surface. (B3)

**selectively permeable\*** The cell membrane is said to be selectively permeable in that it can, to some extent, control which substances pass through it. (B4)

**semelparity\*** (adjective: semelparous) A semelparous species is capable of reproduction only once in the course of its life history; it is said to display semelparity. Compare with iteroparity. (B4)

**semi-conservative replication\*** The process of DNA replication is termed semi-conservative replication, because each new DNA (deoxyribonucleic acid) double helix is formed from one existing 'conserved' polynucleotide strand and one newly synthesized strand. (B9)

**semi-metal\*** A chemical element (e.g. silicon) that displays an electrical conductivity intermediate between those typical of a metal and a non-metal. (B6)

**sensitivity** The sensitivity of the global mean surface temperature (GMST) to a change in a factor that controls climate is the amount by which the GMST would change for a 1% change in that factor (assuming that all other factors stay the same). (B2, A9.2)



**serpentinite** A rock rich in the mineral serpentine, produced by the chemical alteration of peridotite by hot water. (B3)

**sex chromosome\*** In many diploid species, sex chromosomes help determine the sex of the individual organism; human females have a matching pair of X chromosomes, while human males have one X and one Y chromosome which do not match. Compare with autosome. (B4)

**sex-linked gene\*** A gene located on a sex chromosome (the X chromosome in humans and *Drosophila*). Example are the gene for haemophilia in humans and the white-eye gene in *Drosophila*. (B9)

**sex-linked inheritance\*** The pattern of inheritance of a character that is determined by a gene located on a sex chromosome (e.g. the X chromosome in humans and *Drosophila*) and hence shows the same pattern of inheritance as the sex chromosome on which it is located. (B9)

**sexual dimorphism\*** A specific type of polymorphism in which the two sexes have strikingly different forms, e.g. elephant seals, peafowl, sparrowhawks. (B4)

**sexual reproduction\*** A form of reproduction in which part of the genetic material of each of two individuals is combined in their offspring. A haploid male gamete fuses with a haploid female gamete in the process of fertilization. Compare with asexual reproduction. (B4)

**shale\*** A fine-grained sedimentary rock (composed mainly of silt and/or clay), that splits readily into thin layers parallel to the bedding. (B10)

**shallow-focus earthquake** An earthquake with a focus at a depth of less than 70 km. (B3)

**sheeted dyke complex\*** An extensive body of rock composed of many dykes aligned parallel to each other and formed when a dyke is intruded by another and the process is repeated many times. Sheeted dyke complexes form below a mid-ocean ridge, and result in sea-floor spreading. (B3)

**shell\*** Electrons occupying quantum states with the same value of the principal quantum number  $n$  are said to occupy the same shell. The shell with principal quantum number  $n$  can accommodate  $2n^2$  electrons. (B8)

**shell structure\*** A representation of the electron structure of an atom or ion, which shows the number of electrons in successive shells. These numbers are written down and separated by commas, the shells being arranged in order of principal quantum number,  $n$ . Thus the shell structure of the oxygen atom is (2,6). (B8)

**SI units\*** An abbreviation for the Système Internationale d'Unités (International System of Units). SI units are used by scientists all over the world to make measurements according to agreed standards. Examples of SI units are the kilogram for mass, the metre for length, and the second for time. (B1)

**significant figures\*** Uncertainties in measurements mean that measured values should be quoted only with a certain number of digits, and this number of digits is known as the number of significant figures. For example, 10.2 cm is quoted to three significant figures (abbreviated to 3 sig figs) and this means that there is some uncertainty in the final digit (perhaps the value is

10.3 cm or 10.1 cm) but the other two digits are certain. The larger the number of significant figures quoted for a value, the smaller is the uncertainty in that value. (B2)

**silicate\*** A mineral containing silicon combined with oxygen (the  $\text{SiO}_4$  silicate group). *See also* silicate tetrahedron. (B10)

**silicate tetrahedron\*** The arrangement of four oxygen atoms bonded to a central silicon atom found in the silicate ( $\text{SiO}_4$ ) group. The building block for silicate minerals. (B10)

**sill\*** A sheet-like (flat-lying) body of igneous rock formed when magma has been intruded into a crack between layering in pre-existing rocks. A sill is the solidified content of a channel that transported magma; sills may be up to tens of metres thick (usually much less) and can be many square kilometres in extent. Contrast with dyke. (B10)

**sine\*** A mathematical function relating the lengths of two sides of a right-angled triangle. The sine of a certain angle is defined as the length of the side of the triangle opposite to the angle divided by the length of the longest side (hypotenuse) of the triangle. (B7)

**single bond\*** A chemical bond between two atoms; in theories of chemical bonding, it is represented by one shared pair of electrons. (B8)

**sinking\*** (of water masses) The large-scale movement of water from the surface ocean into the deep ocean, which occurs primarily in polar regions. (B2)

**slab-pull force\*** The force acting on a lithospheric plate due to the downwards pull of gravity on the sinking slab of dense oceanic lithosphere at a subduction zone. (B3)

**slate\*** A fine-grained metamorphic rock that breaks along smooth, flat, parallel surfaces (a form of foliation known as slaty cleavage). Slate is formed by low-grade metamorphism of fine-grained, clay-rich sediments. The platy metamorphic minerals in slate (e.g. mica) grow in parallel alignment from clay minerals in response to pressure during deformation. (B10)

**small circle\*** (on the Earth) A circle that is centred on an axis through the centre of the Earth. A small circle usually has a smaller diameter than the Earth. Lines of latitude are small circles centred on the Earth's axis of rotation. A transform fault plate boundary generally lies on a small circle centred on the axis of rotation of a pair of plates. (B3, A13.3)

**soil\*** The mixture of mineral and organic matter occurring above bedrock on the land surface of the Earth. (B2) The mineral matter is produced by weathering of rock. (B3)

**solar constant\*** The average rate at which the energy in solar radiation is intercepted by a unit area facing the Sun, at a location in space above the Earth's atmosphere. In SI units the value of the solar constant is  $1\,370\text{ W m}^{-2}$ . (B2)

**solar electromagnetic radiation** *See* solar radiation.

**solar luminosity\*** The average rate at which the Sun emits energy in the form of electromagnetic radiation. In SI units the value of the solar luminosity is  $3.85 \times 10^{26}\text{ W}$ . (B2)



**solar radiation\*** The energy that radiates from the Sun; it consists mainly of electromagnetic radiation. Used interchangeably with solar electromagnetic radiation in Block 2. (B2)

**Solar System** The Sun and the retinue of objects in orbit around it. (B3)

**solid** See solid state.

**solid state\*** One of the three states in which substances can exist; the other two are liquid and gas. (B1) In the solid state the particles that make up a substance are packed closely together such that their mutual attraction holds them tightly together. The particles do not swap positions. (B2)

**solubility\*** The maximum amount of solute that will dissolve in a given amount of solvent. It varies with the temperature of the solution, and is the amount of solute that will give a saturated solution. The solubility is often expressed as the maximum amount of solute that will dissolve in 100 g of water. (B8)

**soluble\*** A substance that will dissolve in a liquid is said to be soluble in that liquid. (B1)

**solute** A substance that is dissolved in a solvent to form a solution. (B8)

**solution\*** A solution is formed when one substance dissolves in another. For example, salt dissolves in water to produce a solution of salt in water. See dissolve. (B1)

**solve** (an equation) The procedure whereby the unknown value of a quantity is calculated by rearranging an equation to make that quantity the subject of the equation, and by substitution of values of other quantities. (B5)

**solvent\*** A liquid that will dissolve another substance. (B1)

**sorting\*** (of sediments) A measure of the range of grain sizes present in a sediment or a sedimentary rock. If many grains fall within a narrow range of sizes, the sediment is said to be well sorted. If a wide range of grain sizes is present, a sediment is said to be poorly sorted. The degree of sorting can help to indicate the environment in which a sediment was deposited. (B10)

**space** A property of the Universe. Space itself is expanding with the consequence that distant galaxies all exhibit red-shifts and therefore appear to be receding from us. (B11)

**special relativity** Einstein's theory which describes the behaviour of matter and electromagnetic radiation when the energy and speed are extremely large. One consequence of the theory is the equivalence between mass and energy expressed by  $E = mc^2$ . (B11)

**specialized cell** Each cell in a multicellular organism typically becomes specialized in the performance of a particular function, e.g. carrying oxygen around the body (red blood cells), sensing the external environment (nerve cells). (B4)

**speciation\*** The process by which a new species arises by the splitting of one species to give rise to two or more species. (B9)

**species\*** A group of organisms that are similar to one another in appearance and/or behaviour, and that differ in some way from other closely-related groups of organisms. There is usually a significant degree of

reproductive isolation between species that reproduce sexually. The species is the level of taxonomic classification immediately below genus. The second part of an organism's scientific label identifies it as belonging to a particular species within its genus. For example the domestic cat is uniquely identified by the scientific label *Felis catus* (which can be abbreviated to *F. catus* providing there is no ambiguity) in contrast to other species within the genus *Felis*, such as the wild cat (*F. silvestris*). (B4)

**specific heat\*** The amount of heat that must be supplied to one unit of mass of a substance to produce one unit of temperature change. It is usually represented by the symbol  $c$ , and can be expressed in units of  $\text{J kg}^{-1} \text{ } ^\circ\text{C}^{-1}$ . Thus the heat  $q$  supplied to a substance is related to the specific heat, the mass  $m$  of substance and the temperature change  $\Delta T$  by the equation  $q = cm\Delta T$ . The value of the specific heat depends on the substance. (B5)

**spectral distribution\*** A graph showing how the intensity of a spectrum varies with photon energy (or wavelength or frequency). (B7)

**spectral fingerprint** The characteristic absorption spectrum or emission spectrum of a particular substance. (B7)

**spectral line\*** An emission line or an absorption line in a spectrum which indicates that photons of a certain specific energy are emitted (or absorbed) by a particular substance. (B7)

**spectrometer** A device used to measure the spectrum of radiation. A spectrometer can be attached to a telescope to measure spectra of astronomical objects. (B11, A2.2)

**spectrum\*** (plural: spectra) A display (such as a graph or a photograph) of the distribution of light or other types of radiation versus the wavelength (or frequency or energy) of the radiation. (B2) A spectrum may be a continuous spectrum, or may show emission lines or absorption lines. (B7)

**speed** The rate at which a distance is travelled. In SI units speed is measured in metres per second ( $\text{m s}^{-1}$ ). (B3)

**speed of light\*** The speed at which electromagnetic radiation travels through a vacuum. The value is  $3.00 \times 10^8 \text{ m s}^{-1}$  (to three significant figures). (B3)

**spermatozoon\*** (plural: spermatozoa) A haploid gamete produced by a male animal through meiosis. (B4)

**sphere\*** A closed surface that is everywhere the same distance (known as the radius) from the point at the centre. (B3)

**spindle\*** The basket of fine fibres produced during nuclear division, some of which become attached to the centromeres of the chromosomes. (B9, A8.4)

**spiral arms** The arm-like structures in the disc of a spiral galaxy delineated by a greater abundance of bright stars and brightly glowing interstellar gas than exists between the arms. (B3)

**spiral galaxy** A galaxy that has spiral arms. (B3)

**split gene\*** A term used to describe genes in which coding sequences of bases (exons) are interspersed with non-coding sequences of bases (introns). Usually there



are relatively long intron regions interspersed with relatively short exon regions. (B9)

**spontaneous generation** Disproved idea that certain forms of life (e.g. fungi) could arise spontaneously on (for example) bread, provided only that favourable conditions prevailed. (B4)

**spore** A structure produced by some organisms (e.g. fungi, *Hydra*) as part of their life cycle or when adverse conditions prevail. A spore is able to survive adverse conditions and then to produce a new organism if favourable conditions return. (B4)

**square\*** (in mathematics) A number or symbol multiplied by itself. Thus  $2 \times 2$ , or  $2^2$ , is 'two squared' or 'the square of two', and  $m \times m$ , or  $m^2$ , is 'metres squared'. (B5)

**square root\*** The square root of a quantity is the number (or expression) which when multiplied by itself is equal to the quantity. Thus the square root of 16 is 4, because when 4 is multiplied by itself ( $4 \times 4$ ) the result is 16. Similarly the square root of  $a^2$  is  $a$ , because  $a \times a = a^2$ . The symbol  $\sqrt{\quad}$  means 'the square root of', so  $\sqrt{16} = 4$ . Note that the horizontal bar of the square root symbol must cover all of the symbols to be included in the square root;  $\sqrt{16 \text{ m}^2} = 4 \text{ m}$ , but  $\sqrt{16} \text{ m}^2 = 4 \text{ m}^2$ . (B5)

**standard candle** A source of electromagnetic radiation which has a particular luminosity. An example is the tenth brightest galaxy in a cluster of galaxies. (B11, A11.1)

**standard temperature and pressure (STP)** The combined conditions of a temperature of  $0^\circ\text{C}$  and a pressure equal to that exerted by a column of mercury of height 760 mm. (B6)

**star\*** A celestial body that is (or has been) sustained by nuclear fusion in its core. (B3)

**start codon\*** A specific mRNA codon (AUG) which signals the start of translation of the polypeptide chain. Once the first tRNA has bound to this codon, others follow suit. (B9)

**state** See quantum state.

**states\*** Substances can exist in three different states: solid, liquid and gas. (B1)

**steady state\*** If an object, or system, is in a steady state, then its properties are not changing with time, but are constant. (B2)

**stomata** The small openings in the surface of a leaf or stem through which water vapour and other gases pass in and out. (B1)

**stop codon\*** Specific mRNA codons (UAA, UAG and UGA) which signal the completion of the production of the polypeptide chain during translation. (B9)

**stopping voltage** The voltage difference required in order to stop the photoelectrons emitted during the photoelectric effect from flowing in an electrical circuit. The stopping voltage in volts is numerically equal to the maximum kinetic energy of the photoelectrons in electronvolts. (B7)

**strain energy\*** Energy stored within an object or substance when it is stretched, compressed or otherwise deformed. This is a form of potential energy. (B5)

**strange quark (s)** A fundamental particle with electric charge  $-\frac{1}{3}e$ . More massive than either the up quark or down quark. (B7)

**strata\*** Layers of sedimentary rock. (The singular, stratum, is synonymous with bed.) (B3)

**stratigraphy\*** The study of strata and their relationships in time and space. Sequences of strata have long been used to establish a generalized geological succession — the stratigraphic column — made up of geological eras and periods, which when given absolute dates forms the geological time-scale. See also biostratigraphic column. (B10)

**stratosphere** The zone of the Earth's atmosphere immediately above the troposphere and extending from an altitude of about 10 km to about 50 km. (B2)

**strings** A hypothetical description of particles at energies entailed by superunification. (B11)

**stroma\*** The fluid that surrounds the internal chloroplast membranes. This is where the dark reactions of photosynthesis take place. (B9)

**stromatolite\*** A mound-like structure, mainly of sediment, formed by various bacteria, especially cyanobacteria. The bacteria live at the top of the structure, trapping sediment. They are known from fossils as old as 3 500 Ma, and some are still forming today. (B10)

**strong acid\*** An acid that, when dissolved in water, is completely dissociated into aqueous hydrogen ions,  $\text{H}^+(\text{aq})$ , and the accompanying aqueous negative ions. (B8)

**strong interaction\*** A fundamental interaction between quarks and antiquarks responsible for binding them together as triplets inside a baryon or an antibaryon, or as a quark-antiquark pair inside a meson. A residual effect of the strong interaction is responsible for binding protons and neutrons together in an atomic nucleus. (B7) It is one of the four fundamental interactions, and is described by the modern theory of quantum chromodynamics. This describes interactions between particles that possess colour charge in terms of the exchange of quanta called gluons. Strong interactions are characterized by the dimensionless number referred to as  $\alpha_s$  which has a value of about 0.12 at an energy of about 100 GeV. Strong interactions get weaker with increasing energy of interaction. Compare this behaviour with the electromagnetic interaction. (B11)

**structural formula\*** A representation of atoms and bonds in a molecule that shows the order in which the atoms are connected together, as well as the bonds that are involved. The atoms are represented by chemical symbols, and the bonds by lines. In a structural formula, the number of bonds emanating from a particular atom is equal to the valency of the atom in that molecule. The structural formula provides no information on the three-dimensional shape of the molecule. (B8)

**struggle for existence** The consequence of more offspring being produced in a generation than can normally survive to the age when reproduction can



occur. The struggle for existence is one of the three necessary and sufficient conditions for natural selection to occur. (B4)

**subduction** The descent of one lithospheric plate beneath another at a convergent plate boundary. (B3)

**subduction zone\*** A region of the Earth where oceanic lithosphere subducts (sinks) beneath the edge of another lithospheric plate at a convergent plate boundary. (B3)

**subduction-zone accretion\*** The increase in size of a continent by the addition of oceanic sediment, scraped off from subducted oceanic crust at a subduction zone. (B3)

**sublimation** The direct conversion of a solid into a vapour, usually under the influence of heat, without passage through a liquid phase. (B2)

**subscript** A number (or letter) written below the line and in a smaller type, as in the case of 2 in H<sub>2</sub>O (water) and CO<sub>2</sub> (carbon dioxide). (B2)

**sub-shell\*** Convenient (although not entirely correct) way of describing the arrangement of electrons within atoms. Each sub-shell corresponds to a particular combination of *n* and *l* quantum numbers and can accommodate only a certain number of electrons. (B7)

**subspecies** A population from a particular species that shows differences from other subspecies belonging to the same species, sufficient that the different subspecies are recognized by a taxonomist as significantly different but not great enough for them to be considered separate species. Subspecies are recognized by adding a third part to the Latin name for the species. (B9)

**substitution** (in mathematics) The procedure whereby symbols for quantities in an equation are replaced by values of those quantities, or by algebraic expressions that are equal to those quantities. Substitution is often a necessary step if one has to solve an equation. (B5)

**substrate\*** A molecule that binds to the active site of an enzyme and undergoes a chemical reaction there. (B9)

**substrate-level phosphorylation\*** The production of ATP during glycolysis and the TCA cycle by reactions that do not require oxygen. (B9)

**success\*** In biology, the success of an organism is measured by the number of offspring it produces by reproduction that are fully fertile and that survive to reproduce themselves. (B4)

**sucrose** A disaccharide sugar composed of one molecule of glucose and one molecule of fructose. (B9)

**sugar** A collective term for monosaccharides and disaccharides. The characteristic properties of sugars are sweetness and solubility in water. (B9)

**Sun** The star at the heart of the Solar System; the Sun is one of the many stars making up the Galaxy. (B3)

**supercontinent** A very large landmass formed when a number of the major landmasses on Earth become joined together as a result of plate tectonics. (B3)

**supernova** When a massive star reaches the end of its life, its core consists of iron nuclei and there are no further nuclear fusion reactions available to release energy and so support the star against gravity. The outer layers of the star collapse inwards and then suddenly expand outwards in a vast explosion, referred to as a supernova. In the explosion, nucleosynthesis of elements

heavier than iron occurs. Supernovae are responsible for distributing massive nuclei throughout the Universe. (B11)

**superscript\*** A number (or letter) written above the line and in a smaller type, as in the case of 2 in m<sup>2</sup>. See also power (in mathematics). (B1)

**superunification\*** The name given to the process whereby the electromagnetic interaction, the weak interaction, the strong interaction and the gravitational interaction become unified at energies of around 10<sup>19</sup> GeV, the Planck energy. (B11)

**superunified theory** A theory expressing the superunification of the electromagnetic interaction, the weak interaction, the strong interaction and the gravitational interaction. A current proposed superunified theory involves the description of particles as strings rather than points. (B11)

**surface ocean\*** The relatively warm upper region of the ocean, which receives some solar radiation and is mixed by wind and wave action. It is generally restricted to the top 100 to 200 metres. (B2)

**surface temperature** See Earth's surface temperature.

**surface wave\*** A seismic wave that travels at and near the surface of the Earth. There are two types of surface wave: a Love wave and a Rayleigh wave. (B3)

**surroundings\*** In the context of a chemical reaction, everything apart from the system, but more practically it could simply be a beaker and the air surrounding it. (B8)

**sweating** The process whereby fluid (water and dissolved salts) is excreted in the form of drops through pores in the skin. Energy is supplied by the body to evaporate the sweat, and hence the skin cools down. (B1)

**sympatric speciation\*** The formation of two or more species without any geographical separation between the diverging populations. (B9)

**syrinx** The vocal organ in a bird. (B4, A9.1)

**system\*** This is the part of the world in which there is a particular interest; in the context of a chemical reaction, it could simply be a reaction mixture. (B8)

**systematic uncertainty\*** A series of measurements of a quantity may be predominantly larger (or smaller) than the true value because of consistent limitations in the measuring instruments or the method used to make the measurements. Such limitations lead to systematic uncertainties in the measured values. See also accurate. (B2)

**TAG\*** (triacylglycerol) A water-insoluble lipid (or fat) formed by the condensation of one molecule of glycerol with three molecules of long-chain fatty acids (e.g. palmitate or linoleate). (B9)

**tangent\*** A mathematical function relating the lengths of the two shorter sides of a right-angled triangle. The tangent of a certain angle is defined as the length of the side of the triangle opposite to the angle divided by the length of the side of the triangle adjacent to the angle. (B7)

**tauon ( $\tau^-$ )** A fundamental particle (a lepton) with electric charge  $-e$ , which is similar to an electron but with a mass about 3 500 times heavier. Its antiparticle is called the antitauon ( $\tau^+$ ). (B7)



**tauon neutrino** ( $\nu_\tau$ ) A fundamental particle (a lepton) with zero electric charge which may have zero mass. Its antiparticle is called the tauon antineutrino ( $\bar{\nu}_\tau$ ). (B7)

**taxonomic** Taxonomy is the branch of biology concerned with describing, giving a scientific label to and properly classifying living or extinct species. (B4)

**TCA cycle\*** A cyclic sequence of reactions that forms Stage 3 of glucose oxidation. It occurs in the mitochondrial matrix where a 4C molecule (oxaloacetate) reacts with a 2C molecule (acetyl CoA) to form a C6 molecule (citrate). The cyclic sequence of reactions proceeds via another 6C, a 5C and a series of 4C intermediates, and two molecules of carbon dioxide are released. During this cycle, several molecules of NAD.2H and one molecule of ATP (by substrate-level phosphorylation) are also produced. (B9)

**telophase\*** The phase of mitosis in which a complete set of chromosomes (i.e. one member of each chromosome pair) gathers at one end of the cell and an identical set gathers at the other end, prior to cell division. (B4)

**template strand\*** The DNA strand that is used as the template for RNA synthesis during transcription. The other DNA strand, which is not used as a template in RNA synthesis, is termed the non-template strand. (B9)

**tension** An object is in a state of tension when a force acts on it in such a way as to increase its length. (B10)

**terrestrial planets\*** The Earth, and the three other planets in the Solar System that most resemble the Earth: Mercury, Venus, Mars. (B3)

**texture** (of a rock) The description of the particles a rock is made from and of the relationship between them. Texture can be fragmental, when individual mineral grains or rock fragments are cemented together (as in a sedimentary rock) or crystalline, where minerals have grown together so that one crystal interlocks with another (as in an igneous rock or a metamorphic rock). (B3, A9.1)

**theory** See scientific theory.

**thermal equilibrium** An object in thermal equilibrium will maintain a constant temperature. For an object that only exchanges energy with its surroundings in the form of electromagnetic radiation, thermal equilibrium occurs when the rates of emission and absorption of radiation are the same. (B11)

**thermal expansion\*** The increase in length, area or volume of an object as a consequence of a rise in temperature. (B2)

**thermal spectrum** See black-body spectrum.

**thermochemical equation\*** This shows both the balanced chemical equation and the corresponding enthalpy change, where a molar interpretation is given to the former. (B8)

**thermocline** The layer within the oceans in which temperature changes rapidly from the warmer surface waters to the colder deep waters. (B3)

**thermoplastic polymer\*** A synthetic polymer that softens or melts on heating, and solidifies again on cooling, enabling it to be moulded and reshaped easily.

The polymer chains are linked by intermolecular interactions. (B8)

**thermosetting polymer\*** A synthetic polymer which involves a three-dimensional network of covalent bonds. Such polymers cannot be remoulded because their molecules are cross-linked by covalent bonds. (B8)

**till** A muddled mixture of sediment varying in size from large boulders to dust, deposited directly from glaciers or ice-sheets. (B2)

**top quark** (t) A fundamental particle with electric charge  $+\frac{2}{3}e$ . More massive than either the charm quark or strange quark. (B7)

**trace fossil\*** A fossil that preserves evidence of the activity of an organism, e.g. tracks, burrows, and borings, as opposed to a body fossil; often the only evidence we have of extinct, entirely soft-bodied organisms. (B10)

**trade-off\*** The balance necessarily struck by an organism between competing demands for limited resources, e.g. growth and reproduction, or current and possible future effort devoted to reproduction. (B4)

**transcription\*** The synthesis of an RNA molecule using a strand of a DNA molecule as the template. Where the RNA synthesized is mRNA, the information in the DNA is copied in the RNA molecule. mRNA is therefore an intermediate in the flow of information from DNA to a polypeptide. (B9)

**transfer RNA\*** See tRNA.

**transform fault plate boundary\*** A plate boundary in which each lithospheric plate moves parallel to the plate boundary, in opposite directions. (B3)

**transition\*** The name given to the process by which an atom 'jumps' from one quantum state to another with the corresponding emission or absorption of a photon. (B7)

**translation\*** The process of synthesis of polypeptides whose amino acid sequence is derived from the codon sequence in the mRNA. Translation occurs on ribosomes (as polysomes) and also requires tRNA. (B9)

**transpiration\*** The giving off of water by the leaves of a plant. Plants draw water from the soil via their roots. This water is carried up through the stems or branches to the leaves, from where it evaporates through stomata. See also evaporation. (B2)

**transport protein** Proteins embedded in a selectively permeable membrane and which have binding sites specific for a particular molecule, such as glucose, and transport it across the membrane. (B9)

**travel time graph** A common abbreviation of 'travel time-distance graph', a graph of the travel time of a seismic wave against distance or epicentral angle. (B3)

**trend** The general direction taken, for example, by a series of measurements. (B1)

**triacylglycerol\*** See TAG.

**tricarboxylic acid cycle\*** See TCA cycle.

**trigonometry** The process of relating angles in a triangle to the lengths of the sides of the triangle. (B7)

**trilobite\*** A member of an extinct marine group of arthropods confined to the Palaeozoic. Trilobites had an



external skeleton, divided lengthways into three lobes, that was shed periodically during growth. (B10, A2.1)

**triple alpha process** A nuclear fusion reaction in which three helium nuclei (alpha-particles) combine to form a nucleus of carbon-12. (B11, A11.1)

**triple bond\*** A chemical bond between two atoms of a chemical substance which is equivalent to three single bonds; in theories of chemical bonding, it is represented by three shared pairs of electrons. (B8)

**tRNA\*** Small RNA molecules involved in protein synthesis, each of which carries a particular amino acid. Each tRNA molecule has an anticodon (a triplet of bases) which binds to the codon of mRNA. (B9)

**trophic level\*** A useful, but imprecise, term used to denote different stages in a food chain. Each species may be thought of as occupying one or more levels in a particular food chain, and can be part of several different food chains. Autotrophs, herbivores and carnivores represent successive trophic levels in a food chain. (B4, A7.1)

**troposphere** The lowest zone of the Earth's atmosphere, extending from the Earth's surface to an altitude of about 10 km. It is the zone in which weather systems operate and it contains most of the mass of the atmosphere. (B2)

**tsunami\*** Ocean waves caused by movement of the ocean floor by an earthquake under the ocean. Tsunami can travel great distances across an ocean. They have a low wave height in the open ocean, but may increase in height significantly when they reach a coast, and can be very destructive. (B3)

**turnover\*** The balanced breakdown (catabolism) and biosynthesis of cellular materials. (B9)

**typical elements\*** Those chemical elements that occur in Groups I–VII and Group 0 of the Periodic Table. (B6) Their free atoms have outer electron configurations of the type  $ns^x$ , where  $n = 1$  to 7 and  $x = 1$  or 2, or of the type  $ns^2np^x$ , where  $n = 1$  to 7 and  $x = 1$  to 6. (B8)

**U-shaped valley\*** A broad, deep valley with steep sides, having the shape of the letter U. U-shaped valleys are formed by the erosive action of glaciers. In contrast, V-shaped valleys have less steep sides and a narrower floor; they are formed by the erosive action of flowing water. (B2)

**ultraviolet (UV) radiation** A subrange of electromagnetic radiation. It lies between the short wavelength limit (0.4  $\mu\text{m}$ ) of the visible radiation and the X-ray subrange. (B2)

**unassimilated material** Material that is consumed but either passes through the body without becoming assimilated material (i.e. becomes faeces) or is regurgitated. (B4, A7.1)

**unbalanced force\*** A force which is not counteracted by a force of equal magnitude in the opposite direction, and hence causes the acceleration of an object. *See also* Newton's first law of motion. (B3)

**uncertainty\*** An estimate of the likely range of a measured quantity. For example, the length of a piece of string might be quoted as  $10.2 \text{ cm} \pm 0.2 \text{ cm}$ ; here the uncertainty is  $\pm 0.2 \text{ cm}$ , which means that the length is likely to be in the range 10.0 cm to 10.4 cm. (B2)

**uncertainty principle\*** A fundamental result of quantum physics, discovered by Werner Heisenberg, that rules out the possibility of combining definite knowledge of some quantities (such as position) with definite knowledge of certain other quantities (such as velocity). It also limits the accuracy with which certain quantities can be measured simultaneously. (B7)

**unconformity\*** The absence of strata from a particular time interval in a certain region, due either to non-deposition, or to erosion of any sediment that had been deposited. The term also refers to the actual contact between unconformable rocks. An unconformity is often recognized by a difference in the angle of layering in adjacent sets of strata. (B10)

**unit** A quantity that is used as a standard of measurement. For example, a metre and a centimetre are units of length, and a litre is a unit of volume. (B1)

**unit cell\*** The building block of a crystal structure. Each unit cell contains one or more atoms. Its precise shape is determined by the way that the atoms are repeated in three dimensions; it has parallel sides and resembles a box, or distorted box. A crystal typically consists of billions of identical unit cells stacked against each other. (B10)

**universal constant** A quantity which has the same value wherever it is measured in the Universe. For example, the speed of light in a vacuum. (B11)

**universal genetic code** The DNA or mRNA codons are the same in virtually all organisms where the genetic code has been examined; the code is therefore said to be universal. (B9)

**Universe** The entirety of space and all the matter and electromagnetic radiation contained within it. (B11)

**unsaturated compound\*** An organic compound with molecules containing one or more double bonds or triple bonds. (B8)

**up quark\*** (u) A fundamental particle with electric charge  $+\frac{2}{3}e$ . One of the constituent particles of both the proton and the neutron. (B7)

**upwelling\*** The large-scale movement of water from the deep ocean into the surface ocean, which occurs primarily in equatorial regions. (B2)

**urban heat island\*** The surface temperatures in a city or other settlement are slightly higher than those in the surrounding countryside. The region of higher temperature associated with the urban area is known as an urban heat island, and the magnitude of the temperature difference between the urban area and its surroundings is known as the urban heat island intensity. (B2)

**vacuole\*** An organelle that is characteristically found in most plant cells, where it is large and filled with a watery solution and bounded by a membrane. It helps to maintain cell shape, and also acts as a store for water, other small molecules and ions, as well as waste products. Occasionally found in cells of organisms belonging to other kingdoms. (B9)

**vacuum** A region in which there is no matter. (B2)

**valency\*** The valency of an element is equal to the number of atoms of hydrogen that combine with one atom of the element (or, if the element does not combine with hydrogen, its valency is worked out from the known



valency of another element with which it *does* combine). For example, in ammonia (NH<sub>3</sub>) the valency of nitrogen is three. (B6)

**vaporization\*** See evaporation.

**variation\*** (in biology) Individuals within a species show variation, in that no two individuals are exactly alike. Variation is one of the three necessary and sufficient conditions for natural selection to occur. (B4)

**velocity\*** The speed and direction of motion of an object. For example, the velocity of a car could be 50 km h<sup>-1</sup> in a northwest direction; the speed of this car is 50 km h<sup>-1</sup>, which is the magnitude of the velocity. (B3)

**vertebrates\*** Animals with backbones, that today include, in order of their first appearance, five classes: fishes, amphibians, reptiles, mammals and birds. (B10)

**vertical axis** See axis.

**virus** A particle consisting of genetic material contained within a protein coat, and which can only reproduce inside a host cell. These parasite-like particles are significantly smaller than the smallest known cells. (B9)

**visible radiation\*** The subrange of electromagnetic radiation to which human eyes are sensitive. The wavelength of visible radiation falls in the approximate range 0.4  $\mu$ m to 0.7  $\mu$ m. Visible radiation is usually called light. (B2)

**vitamin** An organic compound essential (in small amounts) for the health of an organism that cannot synthesize it. Consequently, supplies have to be obtained from the diet. Certain coenzymes are derived from vitamins. (B9)

**volcanic aerosol** An aerosol emitted by volcanoes, or that results from the gases emitted by volcanoes. (B2)

**volcanic arc** The chain of volcanoes on the over-riding lithospheric plate at a subduction zone. A volcanic arc on oceanic lithosphere may also be called an island arc. (B3)

**volcano** A part of the Earth through which magma and hot gases escape onto the surface of the Earth. (B3)

**volt\*** In SI units, the unit of voltage difference, with the symbol V. (B5)

**voltage difference\*** The electrical energy change  $\Delta E_e$  when electric charge  $Q$  moves through a voltage difference  $\Delta V$  is  $\Delta E_e = Q\Delta V$ . So the voltage difference is the electrical energy change per unit charge,  $\Delta V = \Delta E_e / Q$ . The SI unit of voltage difference is the volt, V. (B5)

**volume\*** A measure of the size of the three-dimensional space that a solid, liquid or gas occupies. The volume of a rectangular block or cube is found by multiplying the length by the width by the height. In SI units, volume is measured in cubic metres (m<sup>3</sup>). (B1)

**vulcanization\*** The process by which sticky natural rubber, a polymer, is made into a dry and highly elastic material by the action of heat and sulfur. The polymer has double bonds along the chain where the sulfur can react to form covalent cross-links between the polymer chains. (B8)

**W boson\*** One of the quanta of the weak interaction. W bosons come in two varieties labelled W<sup>+</sup> and W<sup>-</sup> where the superscripts denote their electric charge. Both W bosons have masses of about 80 GeV/c<sup>2</sup>. See also Z boson. (B11)

**Wadati–Benioff zone\*** An inclined zone of earthquake activity (also known as a Benioff zone) extending several hundred kilometres into the Earth at a subduction zone. A Wadati–Benioff zone defines the position of a cold subducted slab of lithosphere. (B3)

**water** A chemical compound made up of molecules consisting of one oxygen atom joined by two chemical bonds to two hydrogen atoms. The molecule is represented as H<sub>2</sub>O, where H denotes a hydrogen atom, O an oxygen atom, and the subscript 2 that there are two hydrogen atoms in the molecule. (B2)

**water cycle\*** The continuous circulation of water on Earth between ocean, atmosphere, land, biological organisms, etc. It involves water changing its state between solid (ice), liquid (water), and gas (water vapour). (B1) Water within the cycle can be classified as being in one of a number of different types of reservoir. (B2)

**water vapour\*** The gaseous state of water, which forms when water evaporates. (B1)

**watt\*** In SI units the unit of power, with the symbol W. A watt is a joule per second, J s<sup>-1</sup>. (B2)

**wave** A periodic disturbance that transports energy from one place to another. Characterized by its wavelength, frequency (or period) and amplitude. (B7)

**wavelength\*** The characteristic length over which a wave repeats itself. For ripples on the surface of water the wavelength is from the crest (or trough) of one ripple to the crest (or trough) of the next. (B2) Wavelength  $\lambda$  is related to the frequency  $f$  and speed  $v$  of a wave by  $v = f\lambda$ . (B7)

**weak acid\*** An acid that, when dissolved in water, is only partly dissociated into aqueous hydrogen ions, H<sup>+</sup>(aq), and the accompanying aqueous negative ions. (B8)

**weak bond** Non-covalent bonds formed between molecules, or between different parts of the same molecule. So-called because they are much weaker than the covalent bonds that link neighbouring atoms in a molecule. Weak bonds stabilize the three-dimensional shape of biopolymers whereas stronger covalent bonds link the sequence of monomers. There are three main types of weak bond in biology: hydrogen bonds, hydrophobic interactions and ionic interactions. See also intermolecular interactions. (B9)

**weak interaction\*** One of the four fundamental interactions. It describes interactions between quarks and/or leptons (B7) in terms of the exchange of quanta called W bosons and Z bosons. There is no structure that is bound together by a 'weak force'. Weak interactions are responsible for processes such as beta-minus decay (or beta-plus decay) in which quarks change flavour and lepton–antilepton pairs are produced. (B11)

**weather** The day-to-day meteorological conditions at a particular location. (B2)



**weathering\*** The gradual breaking down of rock by the action of water, ice and wind, or biological activity. (B2) Weathering of rock at the Earth's surface may occur by physical breakdown through action such as expansion and contraction, or by dissolving the rock chemically in water, or by physical or chemical action due to living organisms. Contrast erosion. (B3) See also physical weathering and chemical weathering. (B10)

**weight\*** The downward pull on an object due to gravity. Weight decreases on the Moon where gravity exerts a weaker pull on an object than on Earth. The term weight is often used colloquially in contexts where the correct scientific term is mass. (B1) More precisely, weight is the gravitational force acting on an object. An object with mass  $m$  has weight  $mg$ , where  $g$  is the acceleration due to gravity at the location of the mass. Since weight is a force, its SI unit is the newton, N. When people talk about their weight being, say, 60 kg, this is not scientifically correct; it is their mass that is measured in kilograms. (B5)

**WIMPs** Weakly interacting massive particles, proposed as making up the missing mass of the Universe. Their nature is currently unknown. (B11)

**word equation** An equation that is expressed in words rather than in numbers or symbols, for example, density =  $\frac{\text{mass}}{\text{volume}}$ . (B1)

**word reaction\*** An abbreviated statement of what happens in a chemical reaction. The reactants and products appear as chemical names rather than as collections of chemical symbols. For example, hydrogen + copper oxide  $\rightarrow$  copper + water (B6)

**work\*** The work done by a force on an object is the energy transferred to the object. It is equal to the magnitude  $F$  of the force multiplied by the distance  $d$  that the object moves in the direction of the force while the force is acting on it, so  $W = Fd$ . The SI unit for work

is the joule, J. When work is done on an object, the energy transferred may increase the kinetic energy, gravitational energy, internal energy, or some other form of energy of the object. (B5)

**x axis** (of a graph) The horizontal axis of a graph. (B3)

**X boson\*** The proposed quanta associated with the Grand Unified Theory. X bosons come in four varieties with electric charges of  $+4e/3$ ,  $-4e/3$ ,  $+e/3$  and  $-e/3$ . They are predicted to have masses around  $10^{15} \text{ GeV}/c^2$  (corresponding to the energy at which grand unification occurs) and are responsible for turning quarks into leptons (and vice versa) and matter into antimatter (and vice versa). (B11)

**y axis** (of a graph) The vertical axis of a graph. (B3)

**Z boson\*** One of the quanta of the weak interaction. Z bosons are often labelled  $Z^0$  where the superscript denotes that it has zero electric charge. Z bosons have masses of about  $90 \text{ GeV}/c^2$ . See also W boson. (B11)

**zone\*** (of geological time) A subdivision of the biostratigraphic column representing a time period characterized by one or more particular fossil species. (B10)

**zooplankton** Plankton that are animals. (B2)

**zygote** The diploid cell produced when a haploid male gamete fuses with a haploid female gamete in the process of fertilization. (B4)